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Mobilization of Scientific Resources—V, The U. S. Army

THERE have appeared in recent issues of this Journal series of articles concerned with the mobilization of scientific resources in the present war. One of these covered most of the civilian agencies, and another, the organization and subject matter of research carried out directly under the auspices of the Navy. In the present issue, the organization of research and development in the Army is described.

The over-all organization of the Army is described in the first article. As will be apparent from the chart on page 191, the top staff responsibility for research and development resides in the New Developments Division, the director of which has an immediate appeal to the Chief of Staff and the Secretary of War for decisions pertaining to research. Among the principal responsibilities of this Division are the initiation and coordination of research carried on by the various forces and the maintenance of sufficiently close contact with operating units to determine their needs and to assist them in the introduction of new weapons. A complete outline of the activities of the New Developments Division is given by General Borden in the second article of the present series.

Research in the Army is centered in the three large units: Army Air Forces, Army Ground Forces, and Army Service Forces. Most of the research and development in the Army Air Forces is concentrated in the Engineering Division of the Air Technical Service Command at Wright Field near Dayton, Ohio. The wide variety of work carried on at this enormous station is described briefly by General Carroll.

The Army Ground Forces, as the name indicates, comprise combat troops that spend most of their time on the ground. To determine the military requirements of these troops a Requirements Section has been organized. The Development Division of this Section, concerned primarily with the military characteristics required of new weapons and equipment, is described by General Waldron. After requirements are set, they are turned over to one of the Technical Services of the Army Service Forces which has the responsibility of producing the weapon or equipment needed. After the weapon or equipment is in production, it is returned to one of the Service Test Boards of the Army Ground Forces for extensive tests.

As is implied above, the Army Service Forces have the responsibility for research, development, and procurement of all supplies and equipment except those required by the Army Air Forces. Thus the great concentration of research and development is in the Army Service Forces. The staff supervision and coordination are centered in the Research and Development Division described by Colonel Osborne. The operating units of the Army Service Forces in which research and development are carried out are the Chemical Warfare Service, the Corps of Engineers, the Ordnance Department, the Medical Department, the Quartermaster Corps, the Signal Corps, and the Transportation Corps. The research activities of all of these units except the Ordnance Department and the Transportation Corps are described in detail. Papers on the research work of the Ordnance Department could not be prepared in time for this issue and will therefore be postponed until a later date. The Transportation Corps is a relatively young branch of the Service Forces and only recently has set up a board responsible for research and development on rail, water, and land transport equipment. A description of this unit also must await a later issue.

Organization of the War Department and Coordination of the General Staff with Operating Divisions of the Army

CONTROL of all Army activities, domestic and foreign, is centered in the Secretary of War as representative of the President of the United States. This statement is as true in a time of world-wide war like the present as in time of peace. The War Department, headed by the Secretary of War, was created by an act of Congress approved in 1789 and operates in accordance with conditions defined by Congress. The Secretary, acting under the statutes and the executive orders of the President, directs the whole process of organizing, training, and maintaining the Army of the United States.

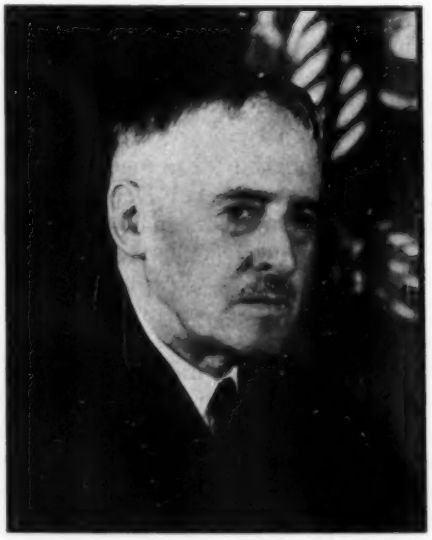
This office has been filled by the Honorable Henry L. Stimson since his appointment in July, 1940. Mr. Stimson occupied a similar position in the cabinet of President Taft and later served in the World War during 1917–18, being assigned to Field Artillery units with the American Expeditionary Force for eight months. Under his experienced direction, the Army of the United States has grown in five years from that of a minor military power to the mightiest force in our history, backed by the greatest production of munitions the world has ever seen.

World-wide war today is fully as much a problem of procurement and supply of munitions of all kinds as one of combat. The top responsibility for Army procurement policies is that of the Under Secretary of War, the Honorable Robert P. Patterson. The Under Secretary came to the War Department from the bench of the United States Circuit Court of Appeals in 1940. His military experience included service with the National Guard on the Mexican Border in 1916 and with the Infantry in the World War, when he received the Distinguished Service Cross for extraordinary heroism in action.

The ranking military aide to the Under Secretary is Lieutenant General William S. Knudsen, with the title Director of Production.

The Assistant Secretary of War, Honorable John J. McCloy, administers for the Secretary of War various matters which do not involve procurement policies or policies of air warfare. Some of these matters are relationships with other agencies, particularly with the State Department; civil affairs, such as the occupation of liberated and hostile countries and Army Emergency Relief; minority racial group policies within the Army; and many problems excluding those involving military operations, which are considered by the Joint Chiefs of Staff and the Combined Chiefs of Staff, referred to below. The Assistant Secretary acts as the Under Secretary of War in the latter's absence, and he acts as the Secretary of War in the absence of both the Secretary and the Under Secretary. Mr. McCloy, who joined the War Department in 1940, served with the Field Artillery in the American Expeditionary Force during the World War.

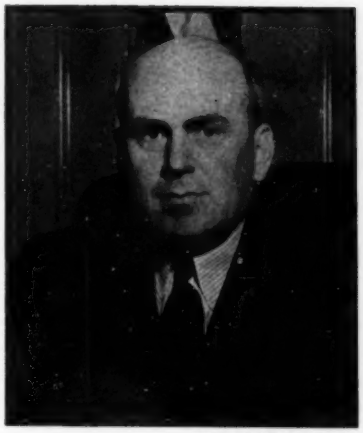
The tremendous development of military aviation in the present war has greatly expanded in scope the duties of the Assistant Secretary of War for Air. The Honorable Robert A. Lovett, who holds this office, came to the War Department in 1940. He had served as a pilot in the United States Naval Service in 1917–18 and was awarded the Navy Cross (U.S.). Mr. Lovett assists the Secretary of War in all matters pertaining to Army Air Forces and the coordination of AAF activities with other governmental agencies. These matters include technical development, procurement and production, organizations, finance, legislation, public relations, and civil aviation (both foreign and domestic).



Signal Corps Photo

HENRY L. STIMSON, SECRETARY OF WAR

Direct military control of all Army personnel, at home



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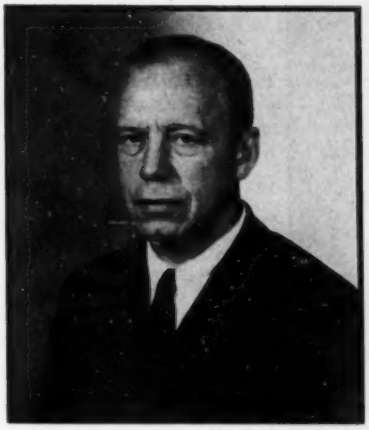
JOHN J. MCCLOY, ASSISTANT SECRETARY OF WAR



Signal Corps Photo

ROBERT P. PATTERSON, UNDER SECRETARY OF WAR

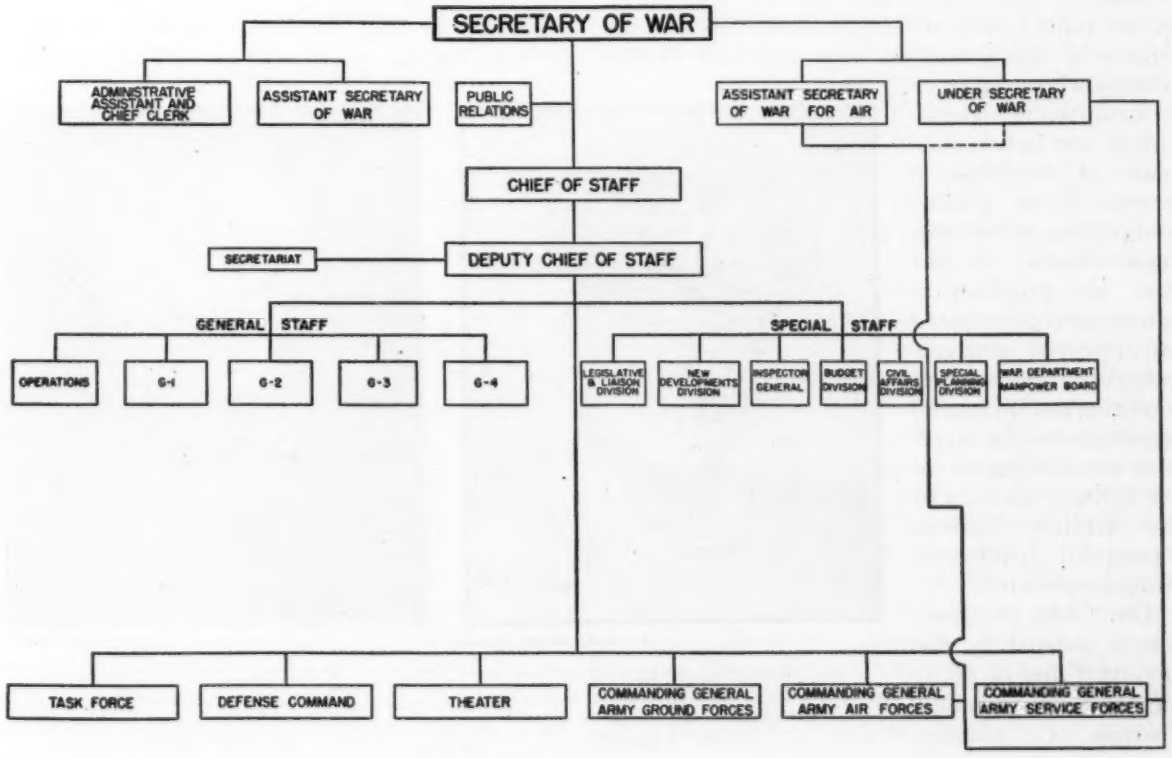
Official Photo U.S.A.A.F.

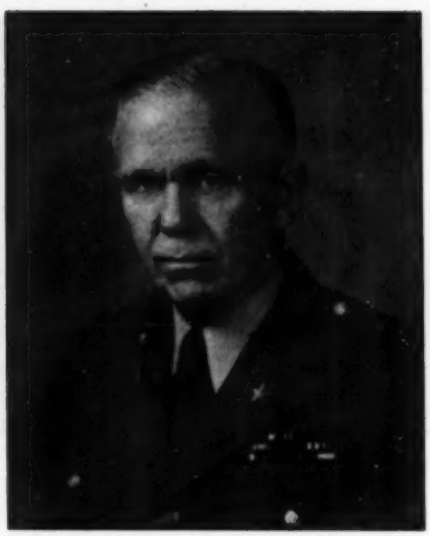
ROBERT A. LOVETT, ASSISTANT SECRETARY OF WAR FOR AIR

and abroad, is exercised by the Chief of Staff, General of the Army George C. Marshall. The Chief of Staff is the executive through whom the President, as Commander in Chief, exercises his functions in relation to strategy, tactics, and operations. The Chief of Staff advises the Secretary of War on all military matters and is in turn charged by him with the planning, development, and execution of the Army program.

The Chief of Staff is the ranking member of the Army delegation in the Joint Chiefs of Staff, made up of Army and Navy officers, who consult together on matters of joint concern to the armed forces, advise the President as to their use, and carry out his plans and policies as

ORGANIZATION OF THE ARMY





Signal Corps Photo

GENERAL OF THE ARMY
GEORGE C. MARSHALL,
CHIEF OF STAFF

Commander in Chief, thus coordinating operations of the Army and the Navy at the top level of command.

Coordination was carried a step further in the present war by formation of the Combined Chiefs of Staff of the United States and Great Britain in 1942. The Army and Navy members of the Joint Chiefs of Staff represent the United States in this group of American and British officers, who collaborate in formulating and executing war policies and plans of the broadest scope. These policies and plans concern strategic conduct of the war, the program of war requirements based on approved strategic policy, the allocation of munition resources, and requirements for overseas transportation of the fighting services of the United Nations based on approved strategic priority.

The Chief of Staff, who is assisted by the Deputy Chief of Staff, Lieutenant General Thomas T. Handy, heads the War Department General Staff and the War Department Special Staff. The function of the General Staff is the development of the Army as a fighting force and assistance to the Chief of Staff in directing field operations. Its activities are divided into five fields, and each division is headed by an Assistant Chief of Staff.

The Assistant Chief of Staff, G-1, Major General S. G. Henry, heads the Personnel Division, which prepares plans and evolves policies governing the procurement of Army personnel and all of the Army's dealings with them as individuals while they are under Army control. The Director of the Women's Army Corps, Colonel Oveta Culp Hobby, is a member of the Personnel Division.

The Military Intelligence Division, G-2, collects, evaluates, circulates, and safeguards military information. Its activities include the assembling of geographical information, the training of intelligence personnel, liaison with foreign armies, detection of disloyalty within the Army, and military censorship. Major General Clayton Bissell heads this division.

The policy field of G-3, Major General Idwal H. Edwards, is the organization, training, and demobilization of the Army. The Organization and Training Division is responsible for the preparation of troop bases and the allocation of personnel in bulk to Army Air Forces, Army Ground Forces, and Army Service Forces. Policy

Signal Corps Photo

GENERAL OF THE ARMY
DOUGLAS MACARTHUR,
SUPREME COMMANDER OF THE
PACIFIC THEATER

Signal Corps Photo

GENERAL OF THE ARMY
DWIGHT D. EISENHOWER,
SUPREME COMMANDER OF THE
WESTERN FRONT

Official U. S. Army Photo

GENERAL JOSEPH W. STILWELL,
COMMANDING GENERAL,
ARMY GROUND FORCES

Signal Corps Photo

GENERAL BREHON SOMERVELL,
COMMANDING GENERAL,
ARMY SERVICE FORCES

Official Photo U.S.A.A.F.

GENERAL OF THE ARMY
HENRY H. ARNOLD,
COMMANDING GENERAL,
ARMY AIR FORCES

on the organization of Army units and certain allotments and allocations to units, is also formulated by this Division.

The Supply Division, G-4, is responsible for broad, basic plans governing the clothing, equipping, feeding, and maintaining of Army personnel and the use of Army property. This Division, headed by Major General Russell L. Maxwell, concerns itself with policy on such matters as the distribution of supplies, transportation, hospitalization, construction, and property accounting.

The fifth of the General Staff sections is the Operations Division, headed by Major General John E. Hull. Here are formulated broad strategic plans for employment of our military forces in the war theaters. Plans for the defense of the United States, for attacking its enemies in any part of the world, and for the strategic deployment of its armies in either case are drawn up by the Operations Division.

Matters somewhat removed from military prosecution of the war are administered by the Special Staff for the Secretary of War and the Chief of Staff. The Civil Affairs Division is concerned with civil matters in occupied areas. The preparation of legislation requested by the War Department and liaison between the War Department and Congress, as well as between the War Department and other agencies of the federal government, are the functions of the Legislative and Liaison Division. Planning and control of the budgeting and expenditure of funds appropriated for the Army by Congress are in the hands of the Budget Division. The Special Planning Division's activities cover preparation for the transition from war to peace of the military and industrial operations of the War Department. The New Developments Division is concerned with possible improvements and innovations in the Army's weapons, equipment, and techniques. Also included in the Special Staff are the office of the Inspector General, who keeps the War Department informed of the state of the Army and its installations, and the War Department Manpower Board, which maintains a continuing survey of employment by the War Department of military and civilian personnel within the continental United States.

Responsibility for the circulation of information about the Army to the press and to the public generally is centered in the War Department Bureau of Public Relations, operating directly under the Secretary of War, and headed by Major General Alexander D. Surles.

When the War Department was reorganized early in 1942, the objectives sought were unity and celerity of control, broad decentralization of detail, and a closer relationship between ground and air operations. The first of these objectives was attained by grouping all domestic Army activities below the General Staff level under three operating heads, the Commanding Generals of Army Air Forces, Army Ground Forces, and Army Service Forces respectively. These three men, General of the Army, Henry H. Arnold, General Joseph W. Stilwell, and Lieutenant General Brehon Somervell, are responsible for carrying out the General Staff's plans to build the Army into a unified team for complete

victory over the Axis. Army Air Forces and Army Ground Forces comprise the troops whose principal duty is combat. Army Service Forces includes those branches whose principal activity is to make it possible for the combat arms to fight by relieving them of the manifold activities necessary to supply transport and maintain troops in the field. Army Service Forces troops are thoroughly trained to fight and are often called on to do so.

The heads of these three great commands report directly to the Chief of Staff. Each of them has a free hand in carrying out his part of the General Staff's plans for training, equipping, and maintaining troops up to the point when they enter a theater of operations outside the continental United States. This decentralization is one of the results of the 1942 reorganization referred to above, and it carries down to the various branches which make up the three great operating forces.

Upon entrance into a theater of operations, all Army personnel pass under the control of the theater commander, who is given complete responsibility for administering his own command to carry out his mission.

"IN time of war, when the nation's existence is in danger, no body of men responds more generously, with greater energy and zeal, to the needs of their country than our scientists and technicians. That was our experience in the first World War; it is also our experience today. Industries and universities have turned their laboratories and their test tubes inside out to give their country what it needed, whether they were summoned or not. Men and women who people those laboratories and wield the test tubes have given us more than we dared hope for. Thousands of lives of our fighting men have been spared, most of the wounded restored to health. I might say at this point that we are recovering for active duty for the Army more than 50 percent of the men wounded. Of course, that by no means includes the number of men that are totally restored to health. Our troops have been equipped with weapons equalling or surpassing those of the enemy; final victory has been brought immeasurably closer as a result of the efforts of our scientists and technicians. With all our grumbling, good-natured or otherwise, the fact is that on the home front we have scarcely felt the war, and that too is in large part to be ascribed to the efforts of our scientific workers."

ROBERT P. PATTERSON
Under Secretary of War

Army Research and Development*

BY BRIGADIER GENERAL W. A. BORDEN

Director, New Developments Division

BRIGADIER GENERAL
W. A. BORDEN

BY law and regulation the War Department is appropriately charged, among other functions, with responsibility for the development of the various types of military equipment required by the Army. This responsibility has been delegated in turn to the various technical agencies of the department. Accordingly, in the Army Air Forces there are technical agencies directly charged with the design and development of equipment peculiar to the Army Air Forces and in the Army Service Forces there are seven technical services respectively charged with the development of ordnance, medical, signal, quartermaster, chemical warfare, transportation, and engineer devices.

The Ground Forces are the customers of the technical agencies of the War Department and specify the military characteristics of the equipment required by the ground combat troops. In a like manner the Air Forces specify the characteristics of the equipment required by the air organizations. Equipment developed by the technical agencies must first be tested for its suitability and be approved by the Ground or Air Forces before it is standardized for issue. The tests are carried out by various boards representing the different combat organizations. Often new equipment is procured in limited quantities for issue to troops in the theaters in order to obtain a service trial of the new items under combat conditions. This is the acid test and no equipment is actually considered fully proven until it has performed adequately in combat. Equipment which is superior, which performs effectively in competition with that of the enemy, and which enables our forces to carry out their missions expeditiously and with the least loss of life is the goal sought in our research and development effort.

This research and development program is directed by qualified leaders in the technical agencies of the War Department. Many of these men have been trained during their service in the department, others have been recruited from civil life; some wear uniforms, some are in the Civil Service, some have been borrowed from universities, laboratories, and other scientific agencies on part time assignments during the war—all have ably conducted the research programs which have done so much to create the fine equipment our Army is using today.

In these activities each of the technical agencies is employing its own resources, its own arsenals, manufacturing establishments, proving grounds, and laboratories. In addition, each is assisted by the engineering groups and laboratories of industry and of our universities. In fact most of the research and development for the technical agencies of the War Department is performed by these industrial engineering and scientific groups. The technical agencies of the War Department are further assisted by the services of the National Inventors Council, by the programs and personnel made available through the Office of Scientific Research and Development, and by the War Metallurgical Committee of the National Academy of Sciences. There is also complete cooperation and coordination on problems of mutual interest between the technical agencies of the War Department, the various Bureaus of the Navy Department, and the agencies of the War Production Board.

The role of science in this war and the part played by the Office of Scientific Research and Development in assisting the War Department to meet its wartime research and development responsibilities have previously been covered in the pages of this publication. OSRD has done a masterful job in mobilizing scientific effort for our Army and Navy and the War Department has received outstanding contributions from the initiative, energy, and creative effort of this great organization.

The experience of the War Department in research matters has produced throughout the

* "The opinions contained herein are those of the author alone and do not necessarily reflect the official opinion of the War Department."

entire structure of the Department the fullest appreciation of the importance of scientific effort in carrying this work forward. The Secretary of War, himself, is extremely conscious of the value of the scientific approach and has given many of the important new developments his personal attention. He is continuously advised by the chiefs of the technical agencies of the War Department in these matters and has at his hand consultants to advise him on the scientific aspects of the military effort. His special assistants are active in supervising and coordinating this work and they have been peculiarly effective particularly in the field of electronics. From the top to the bottom of the War Department the organization is indoctrinated with technically and scientifically trained minds which are actively engaged in the solution of its problems. The War Department plans similarly to maintain this scientific indoctrination in the postwar period.

Recognizing the importance of research and development, the War Department over a year ago established the New Developments Division of the War Department Special Staff. This New Developments Division is charged in general with staff functions which relate to the initiation and coordination of research and development and the military application of new and improved devices and techniques. The Division is specifically charged with the following:

a. Primary responsibility for War Department staff action relating to initiation and coordination of research and development, including development procurement.

b. The exploitation of opportunities for new methods of employing existing weapons and equipment, and the initiation of necessary action relating to the development and prompt military application of new and modified weapons.

c. Coordination and supervision of the introduction and demonstration of new and modified weapons, devices and techniques to the appropriate commanders in the United States and theaters of operations.

d. The rendering of assistance to theater commanders in the solution of technical and scientific problems.

e. Maintenance of close contact with all joint Army-Navy planning and coordinating agencies and committees on new and modified weapons and devices through representation or direct liaison.

f. Supervision over the introduction and the activities of all civilian and military personnel constituting scientific and technical missions to the theaters of operations on matters of research and development.

g. Initiation of necessary action which will insure impartial and conclusive service tests of those weapons and devices which have not received adequate consideration.

h. Maintenance of appropriate relations with other governmental and civilian agencies and the coordination, through the New Weapons Committee of the Joint Chiefs of Staff, of programs of common interest.

i. The making of timely and appropriate recommendations covering standardization, classification, and approval of non-standard items for oversea use.

j. The coordination and reviewing of requirements for special or exceptional items whose future application can be foreseen, but for which the theaters of operations or the combat troops have not established a requirement.

Thus, staff action in the War Department on research and development has been placed with a special staff agency close to the Chief of Staff and the Secretary of War to give impetus, incentive, and over-all supervision to these activities of the Department. Actually its role is that of providing assistance to the technical agencies of the War Department and its success is appropriately attained by aiding those operating agencies to carry out their responsibilities in their respective fields of research and development. The position of NDD in the War Department enables it to iron out differences which may develop between the Service Forces, Ground Forces and Air Forces in their research and development activities and to arrange a direct approach to the Chief of Staff and the Secretary of War for any appropriate decisions which may be required by such higher authority. If the demands for the development of new equipment by the combat troops are not being adequately met, NDD must arrange for appropriate action to be taken by the technical agencies to satisfy the needs which have been envisaged. When the technical agencies have developed equipment considered by them to be satisfactory, but which has not been established as acceptable by the combat forces, NDD must make sure that comprehensive service tests are conducted to demonstrate the tactical usefulness of the device and to insure that the device has received adequate consideration. NDD must be the

crystal gazer of the War Department for special or exceptional devices for which the theaters or the combat troops have not established a need, but for which future application can be foreseen. Thus NDD must let no device which will have future value evade the War Department and be discarded. When these devices have become available, NDD must see to it that they are offered to our forces and appropriately exploited. To be certain that these new devices will be available when needed, NDD must continuously maintain an over-all examination of the research and development program, including the needs of future operations, trends in enemy equipment, and the research work of all agencies. The importance of this forward looking survey cannot be minimized in view of the fact that often eighteen months to three years must necessarily elapse between the inception of an idea and the delivery on the battlefield of standard equipment incorporating this idea. NDD must keep those in charge of War Plans advised of new developments which will come into use so that they will be sure to be fitted into operational plans.

NDD is also charged with the over-all examination of funds involved in research and development programs. This will become very important in the postwar era when funds will be a most controlling factor in determining the extent to which the development of new equipment may be undertaken. The Division will be called upon to exercise a very close review of the budget to be certain that the need for money for research and development is appropriately balanced with the operating requirements of the Army.

Where theaters of operation have need for scientifically or technically trained groups to assist them, it is the job of NDD to arrange to have this aid provided. In this connection, the Office of Field Service, OSRD, has been of great help and, in fact, has been the agency which has provided many of the civilian scientists to the theaters. Permanent groups have been established by the Office of Field Service in several of the theaters and these have currently provided to the headquarters of the theaters technical and scientific assistance in solving complex problems which arise daily. It is impossible to give too much credit to this scientific and technical assistance or to that made available directly by OSRD, or by the technical agencies of the War Department.

Much assistance has been given by NDD in the introduction of new equipment into the theaters by arranging for trained teams to accompany new devices and to demonstrate and exploit their full potential usefulness to the combat troops. The Chief of Staff personally has directed the introduction of certain of these teams to meet initial needs, the requirements for which he has observed, and he has personally sponsored the continuation of this important activity by NDD. These teams have been provided by the Ground Forces, Air Forces, and the Service Forces of the War Department, by the Office of Field Service, and by OSRD. They have been drawn from all sources—military, civilian, industries, laboratories and universities. These teams, in addition to demonstrating equipment, have acquired valuable background which has been brought back to the United States and which has served to guide further research and development. They have thus been a means of determining the user's requirements on the spot, and have been a most important link in bringing the realization of those needs back home in order to enable all technical agencies promptly to attack the problem of supplying them.

NDD has recently sponsored a special scientific group which, accompanied by one of its own officers, visited the European Theater of Operations in order to analyze the effect of our various weapons on enemy morale. Other groups, aided by NDD, have studied battle damage and the performance of standard weapons under combat conditions. The results of these various studies have been made available to all appropriate agencies for the purpose of further aiding the development of effective weapons for our Army.

NDD has consulted with other agencies of the War Department in the selection and prompt assignment overseas of scientists and expert technicians inducted into the service. Such action has been taken to aid in introducing, demonstrating and exploiting in the theaters new and complex equipment upon which these men have been working before they were inducted.

One type of specialty work undertaken by experienced personnel introduced into the theaters by NDD has been in the field of Work Simplification. Men trained in this work have been sent to the theaters to aid in improving the performance of certain selected jobs. Because of the promising results of their work, Work Simplification has been extended to various agencies of the War Department here in the United States which have not previously utilized this approach to improve their efficiency.

With an eye to the future and to enlist the continued aid of engineers and scientists in the development of new and improved devices required by our armed forces, representatives of civilian engineering and scientific bodies with representatives of the War Department and the Navy Department are together formulating a plan for the creation of a Research Board for National Security under the National Academy of Sciences. This Board is to consist of representatives of engineering and science and of the War and the Navy Departments who will formulate and direct research, particularly fundamental research, in those fields of engineering and science which will contribute to our national security. By the time this article is published, it is expected that this Board will be in operation.

It is contemplated that the War Department will place with the Board research and development projects which will engage the creative imagination of the engineers and scientists enlisted by the Board. It is planned that the projects placed with the Board will be broadly stated in order to permit independent action without detailed review, thus allowing the Board full exercise of its initiative. The Board will no doubt carry forward into the postwar period some of the longer range projects of the type now being handled by OSRD. It will continue to be a focal point for bringing the best scientific brains of the country to bear upon many of the research problems of the armed services. It will thus become a team mate with other numerous agencies in bringing science to the further support of the War Department.

In the future, there must be no relaxation in the research and development activities of the Army and the application of science to the art of War must continue to be fully exploited in the over-all program of national defense. Ably assisted by the engineers of industry, by the laboratories, by the universities and by the added scientific effort which will be mobilized under the Research Board for National Security, the technical agencies of the War Department will continue to carry forward their responsibility of developing new and improved equipment for the Army to enable the United States to maintain, in this respect, a strong position of preparedness in the face of possible aggression.

ARMY AIR FORCES

Research and Development at Wright Field

BY BRIGADIER GENERAL F. O. CARROLL

Chief, Engineering Division, Wright Field

BRIGADIER GENERAL F. O. CARROLL

THAT Army Air Forces sky giant hurtling through the air overhead, its wings glinting in the sun, isn't just the answer to a single laboratory problem, but rather the culmination of the solutions to a great number of smaller problems—each a full-fledged research poser on its own.

This is one reason the Engineering Division of the Air Technical Service Command at Wright Field—charged with the research and development of AAF planes and equipment—sprawls over hundreds of acres of Ohio's Miami Valley, employs hundreds of technicians, uses millions of dollars in the latest aeronautical equipment.

This physical layout and its manpower is concerned day in and day out with between 2400 and 2500 different projects—a total which remains fairly constant, despite the approximately 500 items standardized each year, and the many projects closed out for one reason or another.

The far-famed Boeing B-29 Superfortress, currently engaged in bombing the Japanese, offers a most valid example of the type of project presenting so many individual problems.

While the United States slumbered in fitful peace, with but a skeleton air force in 1939, the B-29 was born. AAF flyers then had a handful of B-17's, but standard bombardment airplanes of the time were Martin B-12's and Douglas B-18's.

It was typical of the clairvoyance demanded of military aviation researchers that, in 1939, it was necessary to envision the strategic and tactical considerations applicable three or four years later, when it would be possible to place a new model into production. Moreover, the Superforts were sent into combat ahead of their normal maturity date.

Of prime importance was the requirement that the Superfortress be capable of prolonged operations at altitudes in excess of 30,000 feet, and this one requirement produced some of the toughest problems research men of the ATSC Engineering Division ever have faced. As engineers solved each problem, another sprang up.

High altitude meant reduced temperatures and pressures. The effects of these two circumstances had to be counteracted, for they not only influenced operation of nearly every component of the B-29, but had a definite effect upon the men who flew in them.

As atmospheric pressure went down, engine horsepower was cut proportionately, so that the sea level output was reduced 50 percent at an altitude of 20,000 feet. To keep up manifold pressure, turbo-superchargers were installed and problem number one was solved.

FIG. 1. Fighter pilot wearing the new oxygen mask developed by the Air Technical Service Command, which automatically supplies the proper mixture of air and oxygen under pressure and without inhalation effort.

But ignition systems also were affected by high altitudes. Electricity, following the path of least resistance, tended to "arc over" somewhere in the low pressure area outside the cylinders, rather than leap the spark plug gap and ignite compressed gasoline vapor within the cylinders.

Electrical engineers developed new insulating materials with higher dielectric characteristics, new spark plugs, and new distributor and generator brushes and redesigned the ignition harness to increase creepage distances.

We now had enough manifold pressure and the ignition system was operating, but the B-29 engines still could not operate efficiently. Reduction in pressure had caused gasoline in the tanks and fuel lines to vaporize, resulting in fuel loss and formation of vapor locks within the lines. Tank and booster pumps had to be redesigned.

Still more problems bobbed up. Thin air at high levels—even though extremely cold—gave insufficient cooling. The entire problem of heat transfer was reopened as engineers redesigned engine cowl flaps, oil coolers, and the ducting around the cylinders. They developed new materials which withstood higher operating temperatures.

Thus far, we hadn't touched on the human element. Men, like engines, lost efficiency as atmospheric pressure about them was reduced. As a means of keeping up human manifold pressure—to coin a phrase—engineers designed pressurized cabins for the B-29.

A pressure cabin, they knew, may be used in one of two ways: To eliminate oxygen masks on long missions by maintaining a simulated altitude below 12,000 feet, or to prevent bends by maintaining a simulated altitude below 30,000 feet. AAF engineers chose the former. The B-29 may be operated with a pressure differential up to 6.5 pounds a square inch, which permits flights up to 30,000 feet while maintaining an 8,000-foot cabin altitude.

Originally there were many fears about pressurized cabins. If shell fire penetrated the pressurized area, it was thought the sudden drop in pressure would cause serious injury to the crew, so the Engineering Division's aero-medics made conclusive tests on explosive decompression. A mock-up cabin was equipped with oxygen and communication systems, and a time-pressure recorder designed to make accurate time tracings of rapid pressure changes. High speed motion picture cameras also were installed. The cabin was placed in a high altitude chamber such as is normally used to test effects of altitudes on personnel.

Pressure was maintained within the cabin equal to that existing at approximately 10,000 feet. Outside the cabin, the pressure was reduced to that existing at 35,000 feet. By means of doors with heavy paper apertures of different sizes, it was possible suddenly to puncture the cabin, reproducing the conditions of explosive decompression in combat.

The initial test—and more than 150 others

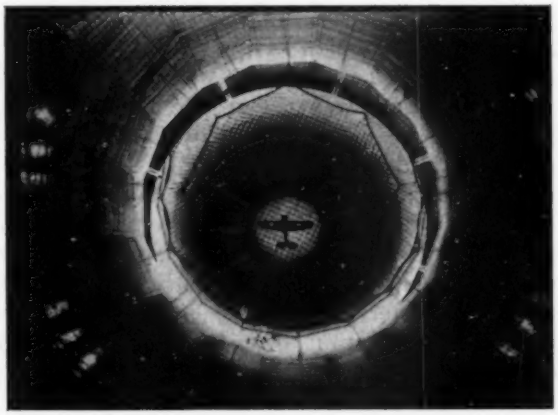


FIG. 2. Vertical wind tunnel at Wright Field. Looking from the base of the tunnel, this photo shows the polished maple surface of the lower test chamber, the net into which models fall at the completion of a test, the free-flying model plane, and the vents through which a 16-foot propeller sucks wind at speeds greater than 100 m.p.h.

with different subjects—was highly successful. No ill effects were noted; there were no latent symptoms. At the moment of decompression the subjects experienced inflation of the chest and abdomen, but they were able to put on their oxygen masks and to unscrew the bolts on the cabin door—a fair indication a pilot would be able to fly his plane to a safer level under similar combat conditions.

The decompression rate—87 pounds a second—was the same as would be produced if the B-29 was ruptured by a 5½-foot hole.

Since turrets and guns had to be operated, and it was impractical to pressurize the entire fuselage, we had a choice of building a pressurized cabin for each gunner or building a large central cabin and design a remote fire control system. Because the latter gave the gunner better visibility, more comfort and more protection from enemy fire, the B-29 has a remote fire control system.

The system was designed to do more than remotely operate the guns, for it included automatic correction for altitude, temperature, ballistic characteristics of the ammunition, and the speed of the B-29, as well as of the attacking plane. These factors all are automatically determined by the computer during tracking and instantaneous and proper adjustment is made in the aim of the guns.

The foregoing are just a few of the problems which surrounded engineers charged with the B-29 project, but they serve to delineate the type of work with which the Engineering Division is faced. Only a streamlined organization and an alert personnel could hope to cope with the diverse problems presented by the research and development of modern military aircraft.

To facilitate that handling—which becomes more complex each year—the Engineering Division was reorganized last year into five main sections:

Service Engineering, which includes engineering shops, aircraft projects, and engineering standards; Aircraft and Physical Requirements, including aircraft, aero-medical, materials, personal equipment, and technical data laboratories; the Propulsion and Accessories Section, including the power plant, propeller, armament, equipment, and photographic laboratories; Radio and Radar Section; Engineering Control.

In general aircraft and physical requirements cover the structural development of air frames and their testing, the human body in flight, the development and testing of materials, flying clothing and emergency rescue equipment, and

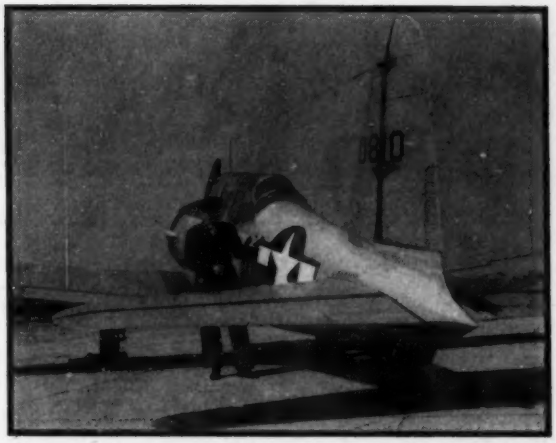


FIG. 3. The historic BT-15 airplane, first aerial craft to have such structural parts as rear fuselage section, tail cone and side panels made of glass fiber plastic.

technical information and records. Propulsion and accessories section handles the development and testing of power plants, aircraft armament, propellers, and equipment for aircraft and for photography.

With the radio and radar section, these are the principal research units of the Engineering Division.

Authority stems from the President, through the Secretary of War; the Chief of Staff; the Chief, Army Air Forces; Chief of Air Staff; Assistant Chief of Air Staff for Material & Services; the Air Technical Service Command; and the Chief of Engineering and Procurement, in that order downward.

ATSC engineers maintain constant, close liaison with NACA, the AAF Proving Ground Command at Eglin Field, Florida, the Army Air Forces Board at Orlando, Florida, the Bureau of Aeronautics, the California Institute of Technology, the Ice Research Base at Minneapolis, Minnesota, and the Ordnance Department Proving Center at Aberdeen, Maryland, as well as with the Navy, allied military forces, and civilian industry.

Whenever the variable necessities of war indicate a need for a new type of airplane or a new piece of equipment, general military requirements are dispatched from the Air Staff in Washington to Wright Field. As an aeronautical pharmacist, the ATSC Engineers fill the prescription, specifying the speed, range, armament, armor, structural strength, stability, maneuverability, materials and ease of production and maintenance, or other performance characteristics.

These specifications are submitted to manu-

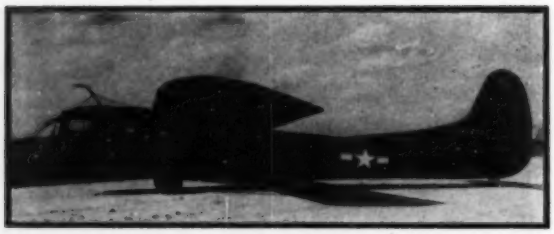


FIG. 4. The new CG-15 glider incorporates new features dictated by battle experience; it has a stronger nose, more controls, and is much more maneuverable than the current operational model, CG-4A.

facturers, then returned to the ATSC in detailed drawings, designs, and descriptions. In the case of a new airplane, the next step is testing scale models in wind tunnels on famed Hurricane Hill, where five tunnels of varying properties are located. With specifications revised to meet tunnel finds, the manufacturer builds a wooden mock-up, providing a visual, three-dimensional plan for the actual plane. Before the plane actually is flown, however, it is subjected to static tests to determine the maximum stress and strain a part will take.

There are other ways, of course, for the AAF to get new airplanes or equipment. By research conceived and carried out by ATSC technicians and engineers themselves, by the initiative of the manufacturer, and by adaptations of existing equipment.

This complicated set-up is a far cry from the original field of October, 1917, when the War Department authorized federal expenditure for "a large aeronautical engineering division and flying field near Dayton, Ohio."

Named McCook Field—after Gen. Anson McCook and his seven fighting sons of Civil War fame—the field grew in two years to 69 buildings and 1500 personnel, covering all functions of the old Materiel Center. A new field of 4500 acres, donated by the city of Dayton, was dedicated as Wright Field, October 12, 1927. Today more than $50,000,000 in equipment is housed in the scores of buildings massed on the slope overlooking the spacious flying field.

Field engineers have wrought many an aeronautical miracle. In 1919, Wright Field experiments produced the Wright Whirlwind, first of the air-cooled radials. Subsequently, to the list have been added superchargers, higher octane fuels, the sextant and earth inductor compass as first applied to aircraft, solo blind landings, automatic landings, night flying, and the first night airways system.

They have shepherded the transition from wood to metal propellers and sponsored the development of liquid-cooled engines when they had lost favor elsewhere.

Such outstanding research and development work—in close collaboration with civilian industry and other branches of the service—is continuing at its accelerated, war-time pace.

And the future holds promise of many startling developments. The aircraft laboratory, always hunting the perfect aero-dynamic structure, also seeks lighter weight without loss of strength. In plastics, more particularly the glass-reinforced plastic fuselage, may come the answer. Entirely new lines of thought will be used in the development of landing gears for the bombers of the future.

Power plant engineers will continue their treadmill search for more horsepower per pound, engines of higher compression to handle synthetic fuels now being developed, and will explore jet propulsion minutely.

Turbo-jet engines may offer one day the answer to the problem of propelling aircraft faster than the speed of sound. Water injection for conventional engines isn't yet completely understood nor fully applied.

A feature of this and future wars is high altitude operations which bring the aero-medics into the picture. They seek means through new oxygen systems and airframe pressurization of allowing flights at heights as yet untouched.

Propeller experts will base post-war experimentation on at least three items: Reversible pitch, contra-props, and de-icing propellers. With rocket-assisted take-offs, reversible pitch propellers fit into a picture of giant airplanes of the future taking off and landing on runways now much too small for existent craft.

On the list at the equipment laboratory are rocket and jet bombs, pilotless aircraft, blind flying, landing and take-off systems, and many other types of equipment.

New materials for every purpose, with emphasis on new types of durals and plastics, are material laboratory responsibilities. The photographic laboratory will work on larger, more penetrating aerial cameras up to 60-inch types, while the technical data laboratory engineering branch continues to develop new uses for high speed photography in the laboratory.

Personal equipment laboratory technicians will be interested in lightweight flak armor, functional clothing, and even more adequate rescue apparatus.

ARMY GROUND FORCES

Development for Army Ground Forces

BY MAJOR GENERAL A. W. WALDRON

Chief of the Requirements Section, Army Ground Forces

MAJOR GENERAL
A. W. WALDRON

THE Requirements Section of the Army Ground Forces, as its name implies, is concerned with the requirements, or needs, of the Ground Force soldier. Its functions are to determine what items of equipment the soldier needs, to take the necessary steps to provide these items, to determine the most effective combination of men and equipment into units, and to furnish the instructional materials for the training of these units in the use of their equipment. Its scope extends to every item of equipment used by the Ground Force soldier both in training and in combat.

The development of equipment is the responsibility of the Development Division, which is assisted in its work by the Service Test Boards. The boards of the combat arms, Infantry, Cavalry, Field Artillery, and Coast Artillery, were established by regulations following the National Defense Act of 1920. Because of the nature of modern warfare, other boards, the Anti-aircraft Artillery Board, the Armored Board, the Landing Vehicle Board, and the Rocket Board, have come into being and assumed a status equal to that of the older boards.

The equipment with which the Requirements Section concerns itself may be divided into three general categories: (a) Things to increase the comfort and efficiency of the individual. (b) Weapons, ammunition, and accessories. (c) Transport.

Most items of equipment were originally ideas, the results of thinking about recognized needs. The source of these ideas may be the battlefield, the training ground, or the laboratory; they may spring from our own or foreign battle or training experience, or may come from the minds of inventors, both in and out of the Army. The idea takes shape and eventually reaches the Development Division where its concrete application to Ground Force needs is considered.

It is first necessary to determine exactly what is to be done, and whether the item under consideration can do it. Next comes the practicability of the particular equipment with respect to bulk and weight. There are very severe limitations on the weight and size of military equipment. Generally speaking, a man can carry no more than half his weight. A great many desirable things which ought to be carried by the soldier will total to a weight and bulk which cannot be

FIG. 1. Soldier dressed for test of mountain and ski troops equipment.

carried by any man no matter how great his physical powers. Similarly, there are restrictions as to weight and bulk in the matter of transport. It is conceivable that a truck could be built which would have an over-all length numbering into hundreds of feet, and a width that would overlap a normal highway, yet the practicability of such a monstrosity is definitely out of the question. Selection, then, becomes an important factor in development. Recognition must be given to the limitation of facilities which could build it. Lastly, there is always the ever present problem of cost. The selective function is again brought into play to conserve funds and facilities for really important ideas.

Once the idea has taken tangible form, appears to fill the need, and meets the limitations of size, weight, cost, and production facilities, the military characteristics of the item of equipment are established. These include the size and weight factors, the purpose of the item, and the general type of construction. The project is now in a form suitable for turning over to one of the Technical Services of the Army Service Forces agencies which are created to produce the things that the Ground Force soldier needs.

On the basis of the military characteristics set up by the Requirements Section the responsible Technical Service will develop the idea into drawings, then into models, then into pilots of the finished product, and finally into the actual thing itself ready for use. Throughout the process these steps are coordinated so that the Development Division of Army Ground Forces is in touch with the project at all times. When the model is produced, for example, obvious faults are recognized and plans made to correct them through this cooperation. Once the model is agreed upon the producer begins to set up facilities to manufacture the item.

When the first piece of the equipment comes off the assembly line the Service Board comes into play. The manufacturers, of course, will have made engineering tests, metallurgical tests, and probably some operational tests. The producing agency of the War Department will also have made some tests, but it is the particular function of the Service Board to subject the equipment to a series of tests approximating as closely as possible the condition under which the item will be used in battle. The true function of the test board is to keep out of the hands of combat troops anything that will be inefficient or harmful, and to pass through to the using troops those things which will be helpful in battle.

The time element is important. It is often said that it is two years from the drawing board to the battle front. While this is not always true, the statement serves generally to emphasize the limitation on achievement of desired results. The element places on the Requirements Section the burden of forecasting the future. To forecast where and under what condition a battle will

FIG. 2. Anti-aircraft unit on alert with 40 mm AA gun. Dragons' teeth of Siegfried Line in the background.

be fought two years hence smacks of astrology. That this forecast has been made with a remarkable degree of success is astounding.

Thus far the development of an idea into a tangible piece of equipment has been discussed. This is only one part of the development problem. A constant scrutiny of battle reports goes on day after day with a view to determining the faults of clothing, food, equipment, and weapons, and to countering enemy measures with more efficient weapons. These reports and comments come from men who have been under fire. Frequently it is necessary to call upon specialists in the fields of electronics, physics, chemistry, metallurgy, and other fields of science, or to reach into the research departments of industry to determine what can be done in the limited time and with the material available. Existing equipment must be made faster, more maneuverable, harder hitting, or less vulnerable. This aspect of the work is less spectacular, but probably more important, than the development of new ideas.

In a world wide conflict in which Ground Force soldiers serve under all conditions of climate and in all parts of the world, the question of providing adequate food and clothing with the necessary facilities for storage is all important. A constant effort is made to improve the food that composes the soldier's rations. While this is of primary interest to the procuring agency, the Quartermaster General, it is of great importance to the Ground Forces that nutritional research is carried on to the end that there is available for the soldier the food that will keep him fit and alert. Problems of storage and handling of food become part of the mission.

Similarly, while clothing is a primary responsibility of the Quartermaster General, it is also one of the responsibilities of the Requirements Section to see that adequate clothing is designed, tested, standardized, and placed in the tables of equipment so that it is available for the Ground Force soldier whether he goes to the arctic or to the tropics, to the mountains or to the sea. The Quartermaster General and the Ground Forces cooperate in seeking to improve the comfort and warmth of clothing while at the same time reducing the weight.

The weight factor is very important in all equipment carried on the person of the soldier. The pack which the soldier carries on his back with its miscellaneous contents of shoes, socks, toilet articles, and other items which must keep him for days on end, must be carried, and carried in a comfortable manner so that there will be no tendency to throw away either the pack or its contents when they become a burden.

FIG. 3. Test of 90 mm AA gun.

Ammunition and weapons are constant objects of investigation. Generally speaking, the man with the better weapon is the man who will leave the battlefield alive. Rifles, carbines, pistols, hand grenades, and other lethal devices designated solely to kill the other man first, fall into this category.

In the larger weapons and ammunition it is a constant battle between offensive power and the defense against it. A weapon is designed which will send a projectile through so many inches of steel. The defense thereupon either puts more steel into the armor or creates some other defensive measure which will defeat the purpose of the weapon. The cycle begins again with the development of more powerful weapons and more defensive armor, until a point is reached where the weapon becomes too cumbersome to operate, or the defensive armor becomes an immovable fortress, and a halt has to be called. The Development Division is forced at this point to turn to the Technical Services for additional research to discover, if possible, more powerful explosives, better metal, or better designs. In the unending process there is no such thing as the perfect weapon.

In the field of transport, development exercises great influence. The best equipped soldier is of

FIG. 4. Test of "Weasel" cargo carrier; hitting the water at 30 m.p.h.

no value unless he can be put in a position where he can fight. The speed of movement today is not the speed of long struggling columns moving on foot across country, but that of fast moving automobiles, trucks, and other motorized equipment. Tomorrow it may be the speed of aircraft. Speed, mobility, and efficiency of operation under adverse conditions are of constant concern. The world at large thinks in terms of good highways. The soldier thinks in terms of rugged, rough ground, full of ditches and depressions, shell holes and mud, sand and rocks. His requirements in items of transport call for best performance under these conditions. He is not so much interested in highways as he will very seldom find them where he is going to fight. Improvements in tires, in automotive power, in efficiency of full track vehicles, are a major problem.

There is also transport which is inherently a weapon, such as the tank or the tank destroyer. The translation of ideas as to fighting vehicles into tanks and self-propelled weapons that meet Ground Forces needs on the battlefield is an important part of the work of the Requirements Section. Although the tank first made its appearance in the First World War, the modern tank is a comparatively recent development, and there is a constant struggle between ourselves and our enemies as to which can appear first on the battlefield with the best piece of equipment.

Supplementary to the development of tanks came the development of what is called self-propelled artillery. In the days of World War I the horse-drawn 75 mm gun was the pride and joy of the artillerymen. Since that day the horse-drawn weapon has all but disappeared. In its place came high speed tractors towing guns of larger caliber and more efficient operation, and heavy cannon in many calibers mounted on tracked vehicles, which move in and out of position in a few minutes, in contrast to the hours formerly needed to emplace artillery pieces.

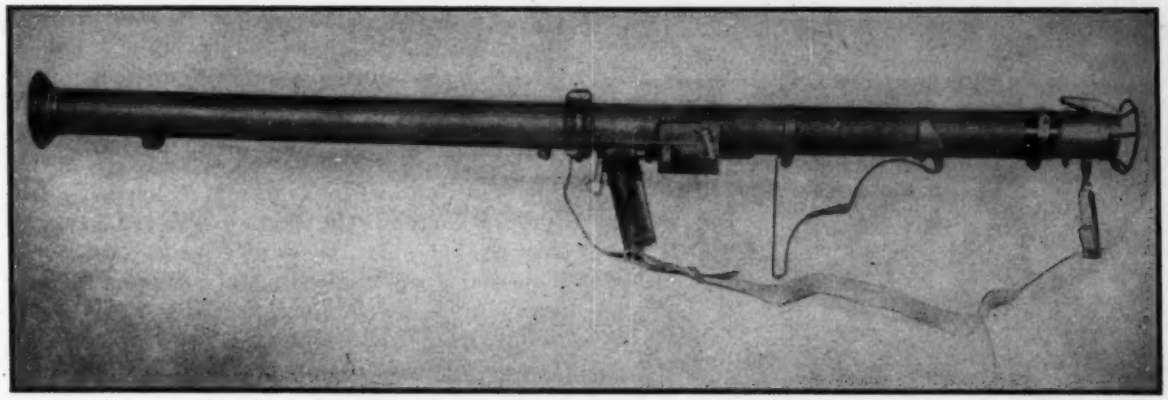
Among the miscellaneous items in which the Requirements Section has been interested and for which it has been partially responsible have been equipment for ski troops and mountain troops; for troops that operate in tropical lands and jungle, in the sub zero weather and the barren terrain of Alaska, the Greenland Ice Cap, and the tip end of the Aleutians; for troops that operate in seaborne, or airborne invasion; for men who walk the decks of mine planters, or stand watch in an exposed anti-aircraft lookout; for the man adrift in open sea; for the man who must work in cold water. The items include equipment to provide hot meals for the soldier in his foxhole; equipment to prevent a horse from being stricken by poison gas; equipment to determine conditions of the upper air; even equipment to serve such delicacies as ice cream to the soldier, dusty and tired from the stress of battle. The list is long indeed, and each item has the careful scrutiny of men who have lived under similar conditions at one time or another.

The Organization Division of the Requirements Section is responsible for the tables of organization and equipment for Army Ground Forces units. This division, too, keeps in constant touch with combat needs by means of study of battle reports and comments. Changes in organization, both in personnel and in the allotment of weapons, keep pace with the ever changing requirements of the battlefield.

The Training Literature and Visual Aids Division of the Requirements Section provides the instructional materials on which Ground Force troops are trained and in accordance with which they are employed in combat. Again, a continuous study of reports from the theaters of operation and an alertness to detect the need for new doctrine or new training material keep official literature abreast of the times. This division must also keep in close touch with both developments and changes in organization, for each new piece of equipment, or change in the personnel or equipment of a combat unit, calls for new instructional methods, or changes in existing manuals.

The work of the Requirements Section is demanding, urgent, and never-ending. Our people have the satisfaction of knowing that their contribution is of great and immediate importance to the war effort—particularly to the front-line soldier.

ARMY SERVICE FORCES



Research and Development Division, Headquarters, Army Service Forces

BY COLONEL R. M. OSBORNE

Former Director, Research and Development Division, Army Service Forces

IN March 1942 a major reorganization of the War Department was undertaken which resulted in the establishment of three major commands, namely Army Air Forces, Army Ground Forces and Army Service Forces, and greatly reduced the strength and functions of the War Department General Staff. Lt. General Brehon Somervell, who prior to the reorganization was the Assistant Chief of Staff, Supply Division, G-4, War Department General Staff, was given command of Army Service Forces. Among other specific functions assigned him at the time of the

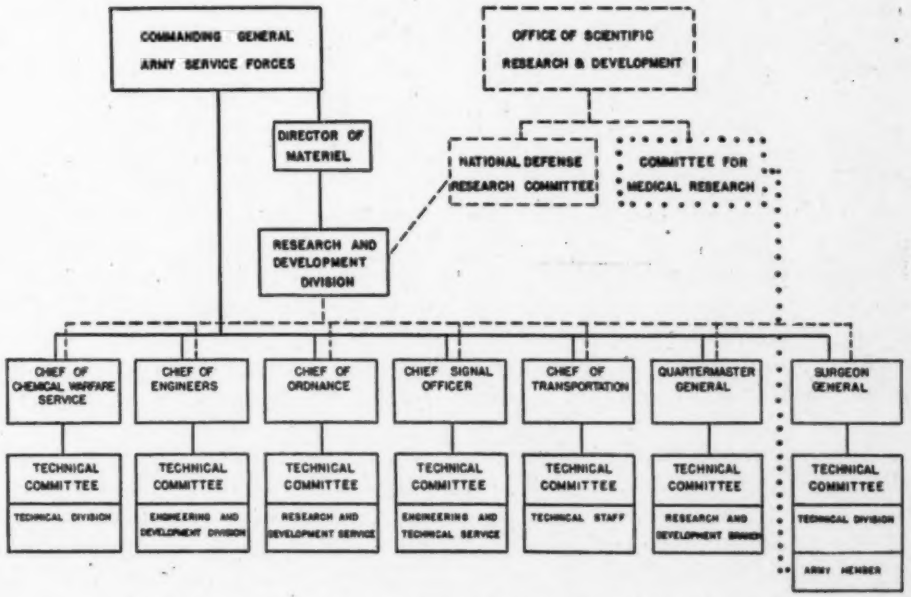


FIG. 1. Research and development activities of army service forces.

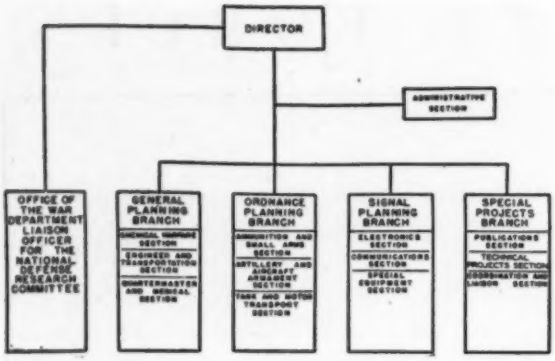


FIG. 2. Organization of research and development.

reorganization was "the direction and supervision of engineering research, development, procurement, storage and distribution of supplies and equipment except those peculiar to the Army Air Forces." In order to carry out these duties in the field of research and development, General Somervell reorganized the Development Branch of his former office into the Development Branch of Requirements Division in his new Headquarters. At a later date, the Development Branch was separated from the Requirements Division and became the Research and Development Division, a separate Division of his Headquarters.

As indicated in Fig. 1, the Research and Development Division exercises staff supervision for the Commanding General, Army Service Forces, over the seven technical services. However, the Director of this Division has a dual function in that he is also the War Department Liaison Officer for the National Defense Research Committee and thus operates closely with the staff and the several divisions of that Committee. The relationship between the National Defense Research Committee and the Research and Development Division is also indicated on Fig. 1.

The mission of the Research and Development Division is to "plan, coordinate and supervise the research and development program of the technical services, to investigate and direct the procurement of non-standard military equipment except items peculiar to the Army Air Forces, and to represent the War Department in its relations with the National Defense Research Committee." All improvements in existing types of equipment also are assigned as the responsibility of this Division.

In order to carry out these functions, the Research and Development Division is organized as shown on Fig. 2. It will be readily seen that the Division is organized to facilitate staff supervision over the seven technical services and to provide liaison for the National Defense Research Committee.

The Office of the War Department Liaison Officer for the National Defense Research Committee assures proper liaison between the various operating units of the National Defense Research Committee and the technical services of the War Department, including Army Air Forces. This office also submits War Department research and development problems to the National Defense Research Committee for solution. The implementation of the function of this office requires the maintenance of a staff of officers, each delegated to follow certain phases of the National Defense Research Committee's program for the purpose of effecting the proper coordination between the Committee's activities and the related activities of the War Department.

The General Planning Branch exercises staff supervision over the research and development activities of the Chemical Warfare Service, Corps of Engineers, Medical Department, Quartermaster Corps, and Transportation Corps. This supervision includes the issuance of directives for the development, modification, and classification of all types of equipment developed by the five technical services named above. It further includes coordination with the using forces with reference to the establishment of military requirements and military characteristics for such materiel.

The Ordnance Planning Branch and the Signal Planning Branch exercise staff supervision over the research and development activities of the Ordnance Department and Signal Corps, respectively. These activities parallel those performed by the General Planning Branch.

The Special Projects Branch is particularly concerned with the procurement of development items for the combat theaters and with the furnishing to those theaters of complete information on the research and development program being carried on in the United States. Further, this branch acts on certain special projects assigned to it by the Division Director.

Whereas a staff agency such as the Research and Development Division does not operate on individual research and development projects, certain items of equipment now familiar to the public have received their impetus from this

Division. However, the direct responsibility for research and development rests in the technical services.

Each of the technical services has in its subdivision, a research and development organization composed of personnel in that service especially qualified in the technical development charged to that service. Each of the research and development agencies has as its director a carefully selected person who is familiar with the detailed requirements of his service and fully qualified on research and development matters pertaining thereto. These officers are, in fact, directly responsible for the development of superior equipment in their respective fields and they are directly responsible to the chief of their technical service for the accomplishment of this mission in a superior manner.

The chief of each technical service has in an advisory capacity a technical committee composed of personnel from all the technical services of Army Service Forces, and from Army Air Forces, Army Ground Forces, the Navy, and the Marine Corps. Each new project is coordinated through this technical committee, thus insuring that the project may be expedited by that agency the best adapted and equipped to furnish a rapid and complete answer.

In order to understand more clearly the interrelation between the using arms, this Headquarters, and the technical services, the history of the development of the 38-ton high speed tractor, M6, is outlined.

The development of the 8″ Gun and 240 mm Howitzer designed for transport on high speed carriages made the development of a suitable tractor to tow these weapons essential. Accordingly, the Chief of Field Artillery, as the user, presented military characteristics for a high speed tractor which would act as a prime mover for the 240 mm Howitzer, M1 and 8″ gun, M1. Similarly, the Chief of Coast Artillery presented military characteristics for a high speed tractor which would act as a prime mover for the 120 mm AA gun.

The purpose of each of these tractors was to provide a high speed track type prime mover for the gun in question and to transport personnel, ammunition, and miscellaneous cargo pertaining to the gun section. The general characteristics of the vehicle were outlined and certain performance requirements were set up. These included the ability to tow the tractor's full load up a 55 percent grade or to tow the full load up a 3 percent grade at 15 miles per hour. The maximum speed required was 25 miles per hour. These military characteristics were coordinated in the Ordnance Technical Committee and on February 9, 1942 they were approved by the Development Branch, Office of the Assistant Chief of Staff, G-4. This approval further directed the procurement of sufficient pilot models for engineering and service tests.

FIG. 3. The M6 38-ton high speed tractor.

Accordingly, the Ordnance Department procured models of the heavy tractor, T22 to be used as a prime mover for the 240 mm Howitzer and 8″ gun; and the heavy tractor, T23 to be used as a prime mover for the 120 mm AA gun. This procurement was made from a manufacturing company who at the same time was developing the 18-ton high speed tractor, M4, for use with the 155 mm gun and 8″ Howitzer. The development of these tractors indicates clearly the standardization of components undertaken by the Ordnance Department. The M6 tractor uses a power train which consists of two M4 power trains in parallel.

Upon completion of the pilot models they were shipped to the Field Artillery and Anti-aircraft Artillery Boards for service tests subsequent to completion of engineering tests at Aberdeen Proving Ground. In the course of the service tests at these boards, numerous deficiencies were reported and recommendations forwarded through Headquarters, Army Ground Forces, to this Headquarters, who in turn directed the Chief of Ordnance to take action to correct these deficiencies.

From the viewpoint of supply, it was essential that, if possible, one type of tractor be made to act as the prime mover for all three weapons. Accordingly, on March 30, 1943, this Headquarters directed that the Chief of Ordnance make every effort to reconcile the differences between the heavy tractor, T23 and heavy

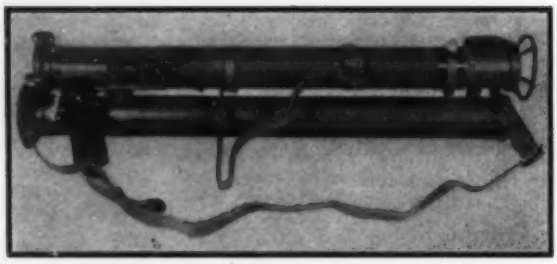


FIG. 4. Bazooka in carrying position.

tractor, T22. These differences were reconciled, and on June 5, 1943, this Headquarters approved the recommendation of the Ordnance Technical Committee that the T22 tractor be standardized as the tractor, high speed, 38-ton, M6. Immediately upon standardization, the Ordnance Department went into procurement on the M6 tractor. Subsequent usage of the tractor by troops in the field and in the combat theaters has resulted in some modifications. These are incorporated on a "no delay in production" basis. The M6 tractor is now in use in the European Theater of Operations towing all three of the weapons for which it was designed to act as a prime mover.

Whereas the above-mentioned 38-ton high speed tractor, M6, filled a clear cut need, which was readily apparent to the using arms, in many instances the development of a spectacular new weapon rests with the chief of the technical service and his development personnel. Such a weapon is the Bazooka, developed by the Ordnance Department and known in Army parlance as the launcher, rocket, anti-tank, M1.

For several years prior to the war the Ordnance Department had under development a launcher for a rocket which could be used to penetrate heavy armor plate. With the aid of the National Defense Research Committee, this weapon developed into the Bazooka and it was demonstrated as an anti-tank weapon in the spring of 1942. The using arms, in this instance, Headquarters, Army Ground Forces, recognized the merits of such a device since it could be used by a team of two infantrymen to knock out a tank. Although there was no specific requirement for a definite number of these weapons for use by the using arms, this Headquarters approved the recommendation of the Ordnance Department on June 5, 1942 for a limited procurement of 5,000 launchers, rocket, anti-tank, M1. Further tests shortly thereafter proved the efficacy of this weapon with the result that the Russian Army, as well as our own, placed requirements for it. On July 17, 1942 this Headquarters approved the recommendation of the Ordnance Technical Committee that the original Bazooka be standardized as the launcher, rocket, anti-tank, M1. Since that date the Bazooka has undergone a continuous process of improvement as a result of tests by the Infantry Board and recommendations from using troops in combat theaters. The present Bazooka may be disconnected in the middle and carried in two parts thereby making it easier to carry, has an improved electrical firing mechanism and a new and unique sighting system. Coincident to the development of the launcher, the Ordnance Department has undertaken the development of suitable ammunition. This development has resulted in the standardization of a high explosive anti-tank round and a white phosphorus smoke round.

An indication that the Ordnance Department has developed a superior weapon in the Bazooka is the fact that the German Army has adopted an 88 mm rocket launcher which from outward appearances was copied directly from our original M1 Bazooka.

In general, it may be said that the purpose of the Research and Development Division is to insure that our troops are supplied with equipment, which from the viewpoint of quality, is second to none. The fact that our troops prefer our weapons and equipment to those of our enemies, as well as our allies, is a true indication of the superlative job that has been done by the technical services in providing those weapons.

Research in the Technical Division Chemical Warfare Service

BY W. C. KABRICH, BRIGADIER GENERAL
Chief, Technical Division, Chemical Warfare Service

BRIGADIER GENERAL
W. C. KABRICH

THE Chemical Warfare Service has come of age. This may seem surprising to those who know that no war gases have been used on the battlefields in the second World War.

It may be equally surprising to some that the Chemical Warfare Service supplies many very important products which have already played significant and, perhaps, deciding roles in the prosecution of the war. I refer to incendiaries of all types, including incendiary airplane bombs, such as those effectively dropped in huge numbers upon industrial installations and other military targets of Germany and Japan. I refer also to the spectacular and highly efficient flame thrower; to all types of screening smokes; to colored signal smokes; and to the 4.2-inch chemical mortar which is so greatly dreaded by the enemy. Most, if not all, of these have been seen by us in moving picture records of the fighting on all fronts. On the defensive side there are equally important developments which protect our soldiers if the use of gas should be initiated by the enemy. These include gas masks, protective clothing, collective protectors, chemical agent detectors, decontaminating agents, first-aid equipment, and protective ointments. All these are second to none, and many of them are decided improvements over types used by other belligerents.

From the very humble beginning in the first World War, through an uncertain and struggling youth when inadequate funds threatened her existence, the Chemical Warfare Service has come of age with a virtual explosive expansion since the beginning of World War II. The story of this expansion is also the story of research, development, and experimentation within the Chemical Warfare Service.

The facilities provided for the conduct of development work in the Technical Division consist of the Research Laboratories, Pilot Plants, and Test Fields at Chemical Warfare Center, Edgewood Arsenal, Maryland; the Development Laboratories at the Massachusetts Institute of Technology in Cambridge, Massachusetts, and the Proving Grounds at Tooele, Utah and elsewhere. The Development Laboratory for the study of incendiaries at Columbia University, New York City, established in the first year of the war, was recently consolidated with a similar group at Edgewood Arsenal, Maryland. These installations have made possible a rapid progress in all phases of an intensified and coordinated program under a unified command. An adequate description of each of these units and their technical capabilities would be difficult without considerable detail. The following simple statements may be helpful in grasping the scope and nature of their work.

The Chemical Warfare Service, Technical Command, Edgewood Arsenal, is the basic research organization of the Chemical Warfare Service. Its laboratories consist of a large centralized building with adjacent smaller laboratories for performing more hazardous operations with munitions; the required machine shop facilities for fabricating experimental equipment and apparatus; a pilot plant area for the development of chemical manufacturing and munitions filling plants; test fields for experimentation with munitions of all types, and toxicological laboratories including animal facilities to study the toxicity of chemical warfare agents and their physiological mechanism when applied to animal life. The Toxicological Section is at present under the supervision of the Medical Division, Office of the Chief of the Chemical Warfare Service.

The Chemical Warfare Service Development Laboratory at the Massachusetts Institute of Technology consists of a recently constructed building originally designed for the Department of Chemical Engineering at that famous institution, and a group of highly skilled and technically trained officers and civilians. This laboratory conducts small scale pilot plant operations for the manufacture of chemical agents. It also

FIG. 1. Research Laboratories, Chemical Warfare Center, Edgewood Arsenal, Maryland.

conducts studies of problems connected with protective ointment. These include problems connected with development of gas masks, with all the various ramifications of adsorbents, filters, and materials of construction; the development of protective fabrics and their applications; and development of devices for detecting all types of war gases, as well as special analytical methods required in the field and manufacturing plants. Numerous instruments required by chemical warfare troops in the field and in manufacturing installations have also been a contribution of this laboratory.

Dugway Proving Ground at Tooele, Utah, was established by the Chemical Warfare Service early in 1942. This facility provides a large unrestricted area where sizable quantities of chemical munitions may be fired from mortars and other weapons or dropped from aircraft. The functioning of all types of experimental munitions may be tested here. The location provides an excellent means of establishing the behavior of gas and smoke munitions as well as incendiary bombs. Test fields elsewhere permit a similar study of chemical munitions and gas cloud behavior under semi-tropical conditions.

In addition to its own facilities, the Chemical Warfare Service has made extensive use of the research facilities of large industrial organizations in the solutions of its many and varied problems. I cannot speak too highly of the cooperation and the help that has come to the service through these agencies.

Still another important contribution to the developments of the Chemical Warfare Service has been made by the National Defense Research Committee, of the Office of Scientific Research and Development. Through this agency, the services of the most capable scientists and engineers have been made available to the country on chemical warfare problems. The activities of the various chemical warfare facilities and the pertinent divisions of the National Defense Research Committee have been coordinated and integrated through a Joint Steering Committee, composed of Chemical Warfare Service personnel and members of the National Defense Research Committee.

Another important factor in the success of the Technical Division during these war years which cannot be over-emphasized is the large number of officers who were called from their normal

civilian activities to become a part of the Technical Division. These men were recruited from the scientists and the engineers of the country, many with former chemical warfare experience and training and all with industrial chemical and university background. With the advent of war these officers were called to active duty and assigned to places of responsibility in the rapidly expanding organization. These men, with a nucleus of well qualified civilians who had had years of chemical warfare research experience under the handicapped condition of the war interim period, are still carrying on the development work at the various Chemical Warfare Service installations.

As may be expected, many of the activities and accomplishments of the Technical Division with these enormous research forces are among the military secrets of the U. S. Army. It is possible, however, to indicate in broad outline what some of those accomplishments are. Since chemical warfare has not been used in this war and many people are at least partially familiar with chemical agents and methods of protection, emphasis in this article has been placed on the more active and less widely known developments of the Chemical Warfare Service.

MECHANICAL SMOKE GENERATOR

During the last war, artificial screening smoke was produced from comparatively expensive materials and in comparatively small amounts. The munitions used were candles, pots, spray tanks and bursting shell, and bombs. These were totally inadequate to produce screening smoke

FIG. 2. M2 smoke generator. Operation from a fox hole.

FIG. 3. 4.2-inch chemical mortar in action.

in the amounts required in the present war. There was need for equipment to produce very large volumes of smoke from inexpensive materials. This was met by the development of a totally new principle for producing oil smoke in a rugged and portable generator which converts oil into dense white persistent smoke. By the use of these generators, whole cities or areas can be screened from aerial observation and bombardment. This equipment has been used operationally and has saved lives of many American soldiers and untold quantities of critical material.

THE CHEMICAL MORTAR

The Chemical Mortar was known in the last war as a smooth-bore mortar with a tumbling shell which had a relatively short range. Much work was done on this mortar during the interval between the two wars. Its barrel was rifled to produce true flight. The barrel, the baseplate, the standard, and the shell were improved. The range was about doubled. But there was still much need for further improvement. An intensive program of development has increased the range to about four times that of the original mortar, has strengthened the baseplate to ten times its pre-war strength and has greatly added to the usefulness of the weapon. It has become famous for its smoke, incendiary, and high explosive shells. It may be disassembled, carried by three men into inaccessible places and set up in a few minutes time. Its deadly accuracy and high rate of fire has silenced many a German strong point.

FLAME THROWERS

Flame throwers were used in a small way in World War I but proved to be far more deadly

FIG. 4. Portable flame thrower in action.

to the Operator than to the enemy against whom it was used. A blast from a flame thrower attracted the fire of the enemy from all arms and the life expectancy of a flame thrower operator, after the first blast was not in excess of two or three seconds. The range was very short, not exceeding about twenty yards, the ignition system was unreliable and the mechanism was more than necessarily complicated. When this crude weapon came from the research overhaul, the number of its parts was reduced to less than half as many as before; the ignition system was reliable and could be fired immediately after immersion in salt water for twenty-four hours; and two types of fuel had been developed—the ordinary liquid fuel which provides a huge burst of flame and a thickened fuel which is thrown for a considerable distance. Tactics were developed which protected the operator during the few minutes required to use the flame thrower. This weapon is terrifyingly effective and in many instances completely demoralizes the enemy. Its primary value is in attacking pill boxes, bunkers, and embrasures. It has been particularly effective in the Pacific Ocean area. Tank-mounted flame throwers have also been developed. The full potentialities of this weapon have not been realized as yet, although many military experts predict that it will have a deciding influence on pending operations of all theaters of war.

BOMB CLUSTERS

The dropping of bombs from airplanes is a good example of the complexity of the development of an essentially extremely simple operation. In World War I when bombs were dropped, they were simply heaved overboard, one at a time. Effective methods have been developed to drop numerous bombs in large clusters and to provide means by which clusters may open and suitably disperse the bombs in an effective pattern. The means by which the bombs are held in a cluster is called the "adapter." Two kinds of adapters have been developed giving rise to the aimable cluster and the quick opening cluster. Aimable clusters are dropped from high altitudes and certain time fuses set to release the bombs from the clusters at a predetermined altitude. These clusters have an all-over, streamlined casing and tail fins designed to give them true flight. Quick opening clusters are dropped from comparatively low altitudes and have means for their opening and the release of the bombs immediately after the clusters clear the planes. The principal clusters for which racks are provided in the bomb bays of airplanes are the 100-lb. size and the 500-lb. size. Means must be provided for aiming all bombs as they leave the airplane. The several fillings contained in bombs require specific modifications in the clusters. The number of bombs contained in a cluster may vary from three or four to nearly two hundred.

INCENDIARIES

Although incendiaries have played a role in battle since the dawn of history, the first modern incendiary munitions were used in the first World War. Among them were incendiary bullets and anti-aircraft shell, used mainly against observation balloons, flame throwers against personnel, and incendiary bombs against inflammable targets. About ninety such bombs were dropped over London by one airship during the first zeppelin raid in 1915.

The great development of aviation before and during the present war has made the incendiary bomb a weapon of primary importance. The world is familiar with the part played by

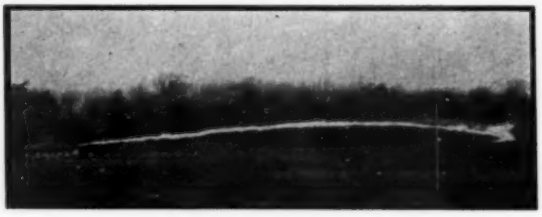


FIG. 5. Mechanized flame thrower.

incendiary bombs in the great air raids of the present war when thousands of tons of such bombs are dropped in a single air raid upon cities, factories, oil storage plants, railroads, storehouses, and other installations. All incendiary munitions in use by the U. S. armed forces have been developed by Technical Division, Chemical Warfare Service. Among these are the following: magnesium bombs, thermit bombs, solid oil bombs, and white phosphorus bombs. The white phosphorus bomb acts also as a casualty producing munition. White phosphorus is also loaded in hand grenades, 4.2-inch chemical mortar shell, and other munitions.

FIG. 7. White phosphorus hand grenades.

COLORED SIGNAL SMOKES

Until recently signal smokes were usually either white or gray, and they were frequently difficult or impossible to distinguish from other battle smokes. A definite need existed for smokes of several distinctive colors so that definite and unmistakable signals could be transmitted over considerable distances. Investigation determined that excellent colored smokes can be produced by volatilization of suitable dyes in a suitable burning mixture. Many types of dyes were tried, and it was found that as a class the anthraquinone dyes were best adapted although no general principle of selection could be formulated. Smokes of the following colors were developed: yellow, red, orange, violet, green, and blue. These are all brilliantly colored, and they can be easily distinguished at considerable distances.

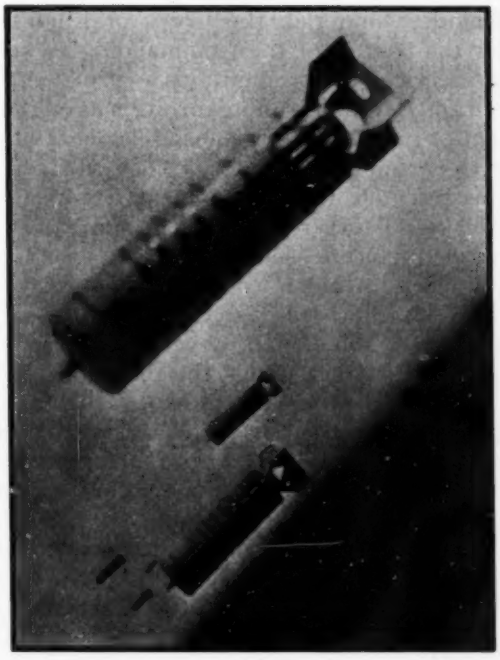


FIG. 6. New aimable cluster of incendiary bombs leaving plane.

GENERAL

Little has been said in this article of chemical warfare agents and the necessary protection against them. It would seem desirable to assure the reader at this point that this vital part of chemical warfare has not been neglected. Facilities for the production of agents, both old and new, have been installed and operated; means and devices for protecting the individual have become standard articles of issue. Every Allied soldier who approached the Normandy beaches on D-Day last June was fully equipped to protect himself against any gas that might be used by the enemy in that important operation. Suffice to say that when as and if the use of gas is initiated by our enemies, our armed forces will be in a position to retaliate effectively through the efforts of the Technical Division of the Chemical Warfare Service.

Research in the Corps of Engineers

BY BRIGADIER GENERAL JOHN W. N. SCHULZ

President, Engineer Board, U. S. Army

The highly mechanized character of World War II, its global nature, the extended lines of communication, the great destruction created in our path by demolition, artillery, and air bombardment, and the sweep and speed of movement of our forces, have imposed equipment demands on the Army Engineers unheard of in any previous war. The principal field agency of the Chief of Engineers for carrying out the work of research and development pertaining to this equipment is the Engineer Board, located at Fort Belvoir, Virginia. In presenting the following article, the President of the Engineer Board desires to acknowledge the assistance given by various members of the Board staff, as well as by the Office of the Chief of Engineers, in preparing this story of Corps of Engineers research and development.

THE present global war is to an almost unbelievable extent an Engineer's war. The ultimate goal of research in the Corps of Engineers is to assure that our Engineer soldiers, as well as the troops of other arms and services who use Engineer equipment, are furnished with the best and most improved material that can be devised to aid them in accomplishing their mission efficiently and effectively.

BRIGADIER GENERAL JOHN W. N. SCHULZ.

The mission of the Engineer soldier in time of war, as of all American troops, is destruction of the enemy. His methods of accomplishing this mission, however, differ from those of other soldiers. His primary functions are to increase the combat effectiveness of our troops, to facilitate their movement, and to hinder the movement of the enemy. He assaults and destroys hostile fortifications and strong points. He is prepared to fight as infantry. He hunts tanks and builds tank obstacles. He clears mine fields and removes booby traps. He constructs, maintains, and improves the routes of communication; he builds airfields, ports, railroads, roads, and pipelines; with his boats and bridges, he spans rivers. He operates beaches for the landing of supplies. He houses the Army and its paraphernalia. The Engineer soldier is responsible for water supply. He operates power plants and water and sewage systems. He surveys friendly and enemy territory and supplies maps to field armies. He is a master of camouflage. He constructs protective works; he builds obstacles and road blocks, and lays mine fields to hinder enemy movement; he carries out demolitions. He uses many kinds of equipment; and upon the superiority of that equipment over enemy equipment depends, in large measure, the success of our forces.

THE RESEARCH ORGANIZATION

To preserve superiority of equipment and to insure practical application of scientific advances to Engineer materiel, the Corps of Engineers, under the control of the Commanding General, Army Service Forces, maintains a permanent research and development organization as one component of the large research establishment of the War Department.

This research and development organization, as well as all other technical activities of the Corps of Engineers, is administered by the Chief of Engineers, Major General Eugene Reybold. Within the Office of the Chief of Engineers, technical research and the development of Engineer equipment are under the direction of the Assistant Chief of Engineers for War Planning, Brigadier General L. D. Worsham, with supervisory responsibility, except for items pertaining to mapping, assigned to the Engineering and Development Division of the Office of the Chief of Engineers. The Chief of the Engineering and Development Division is Colonel H. F. Sykes, Jr.

The responsibilities of the Engineering and Development Division include maintenance of liaison with research and development agencies outside the War Department, analyses of equipment requirements, coordination with the using arms and services, determination of priorities, rendition of such technical aid as may be required in the preparation of designs and specifications for Engineer equipment, the direction of research and development work on Engineer equipment, and the making of recommendations regarding

FIG. 1. The Engineer Board, Fort Belvoir, Virginia.

the adoption of equipment for use by Engineer troops. In carrying out these responsibilities, the Engineering and Development Division receives assistance from other divisions of the Office of the Chief of Engineers, including the Military Intelligence Division, the Military Construction Division, and the several divisions under the Assistant Chief of Engineers for Military Supply.

The principal research agency of the Corps of Engineers is the Engineer Board, which was formed in January 1933 and permanently stationed at Fort Belvoir, Virginia, then known as Fort Humphreys, Virginia. Prior to the establishment of the present Engineer Board, earlier boards were appointed from time to time to consider and report upon suitable field equipment for Engineers. As far back as 1870 there existed an Engineer Board at Fort Totten, New York, whose mission was to test all new items of equipment, including bridges, demolitions, torpedoes, and submarine mines. Intimately connected with this early board was Brigadier General Henry L. Abbot, a distinguished and brilliant officer of the old Corps of Engineers. This board remained at Fort Totten until about 1910, when it was moved to the new Engineer post at Washington Barracks, D. C. and later was replaced at Fort Humphreys (now Fort Belvoir), Virginia, about 1922, by the "Board on Engineer Equipment," forerunner of the present Engineer Board.

THE ENGINEER BOARD

The present Engineer Board, while carrying out its duties under projects or directives issued by the Chief of Engineers or higher authority, exercises wide freedom in prosecution of the research and development work assigned to it and is privileged to indicate desirable improvements in equipment and to submit new research and development projects for the consideration of the Chief of Engineers. Briefly, the mission of the Engineer Board is: (a) To develop and improve Engineer equipment for use by Engineer troops and troops of the other arms and services. (b) To examine, test, and improve commercial engineering equipment as may be needed for military application. (c) To study, investigate, and report on such subjects as may be referred to the Board by the Chief of Engineers. (d) To exercise technical supervision over development work on Engineer equipment by other agencies which may be authorized or directed to assist the Engineer Board. (e) To originate and submit to the Chief of Engineers recommendations looking to the improvement of the Engineer service.

The term "Engineer equipment" is not used in the restricted sense that the equipment developed is for the sole use of Engineer troops. The activities of the Engineer Board include the development of certain types of equipment, for which the Corps of Engineers is responsible,

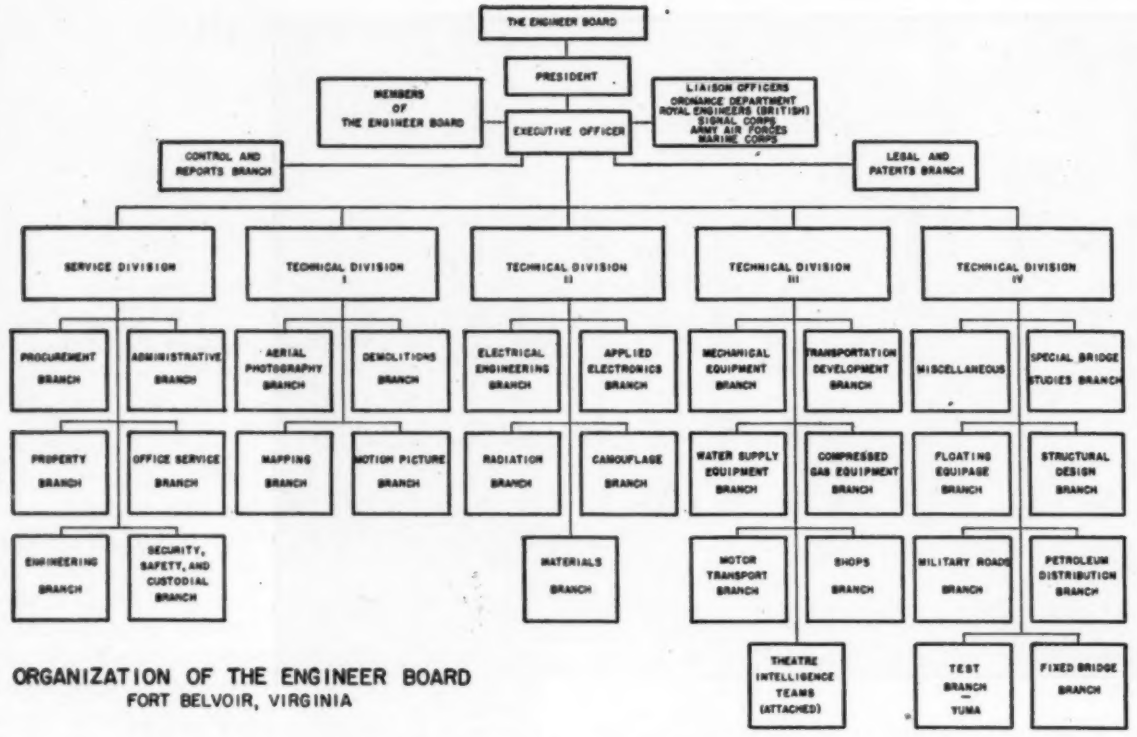


FIG. 2. Organization of the Engineer Board.

utilized by other branches of the Armed Forces, such as anti-aircraft searchlights, barrage balloon equipment, portable landing fields, and camouflage materials and equipment. Although the Engineer Board is an agency of the Army Service Forces, a large portion of the work of the Board relates to development or improvement of equipment to meet urgent requirements for Engineer and other troops of the Army Ground Forces and the Army Air Forces. Some of the results of research of the Board find useful application, as well, in the Navy and the Marine Corps.

Although the Engineer Board operates on the policy that the research scientists and engineers of its staff have full technical responsibility for the accomplishment of their work, these duties are performed in accordance with principles and policies directed by the official Engineer Board, which consists at present of six officers of the Corps of Engineers; the President of the Engineer Board, Brigadier General John W. N. Schulz; the Executive Officer, Colonel William J. Matteson; and the Directors of the four Technical Divisions —Lieutenant Colonel Giles L. Evans, Jr., Technical Division I; Lieutenant Colonel J. Arthur Hamilton, Technical Division II; Lieutenant Colonel Karl F. Eklund, Technical Division III; and Colonel Carl W. Meyer, Technical Division IV. This Board supervises the Technical Staff, coordinates the research activities, reviews the completed work, and makes recommendations to the Chief of Engineers.

The Technical Staff of the Engineer Board, as indicated on the accompanying chart, is organized into four Technical Divisions, a Service Division, and two separate branches—a Control and Reports Branch, and a Legal and Patents Branch.

Each technical division is composed of a variable number of branches, charged with the development of specific types of equipment or research along specific lines of physical science and engineering. In turn, the branches are divided into sections which undertake certain subdivisions of the work. For example, the Electrical Engineering Branch has sections devoted to the development and improvement of searchlights, of searchlight mirrors, of electrical power supply equipment, and of illumination equipment.

The Service Division, under Major Louis C. Verrette as Director, relieves the technical personnel of all non-technical matters, such as procurement, shipment and receipt of property, and the maintenance of fiscal records and military

and civilian personnel records. In addition, the Service Division is responsible for drafting, preparation of specifications, photography, and reproduction. Hence, the technical personnel is enabled to devote maximum time to research, development, and testing.

The Legal and Patents Branch under Major John W. Poteet as Chief, supervises all matters relating to inventions, patents, licenses, and other legal problems having to do with the work or operations of the Board and its technical staff. The Control and Reports Branch under Major Henry W. Brands as Chief, is the internal coordinating agency for the technical staff and supervises the preparation, publication, and distribution of Engineer Board technical reports.

In carrying out its development work, the Engineer Board maintains close contact and coordination with the Engineer School of the Army, located at Fort Belvoir, which is the central seat of Engineer learning and training for our land forces. Also, close liaison is maintained by the Board with other parts of the armed forces. At the present time liaison officers from the Ordnance Department, the Army Air Forces, the Signal Corps, the Marine Corps, and the Royal Engineers of the British Army, are on duty with the Engineer Board. The Engineer Board works in close cooperation with the Navy Department, including the Marine Corps, and with various arms and services of the Army to which particular subjects of development are pertinent. Engineer and other troops and the Service Boards of other interested arms and services are utilized as necessary in service tests to determine the usefulness and practicality of equipment developed. New or improved equipment in certain cases is also subjected to the acid test of actual combat service in the theaters, before being standardized and approved for large-scale production and issued to the troops. In any event, criticisms and suggestions from the using troops in the theaters are

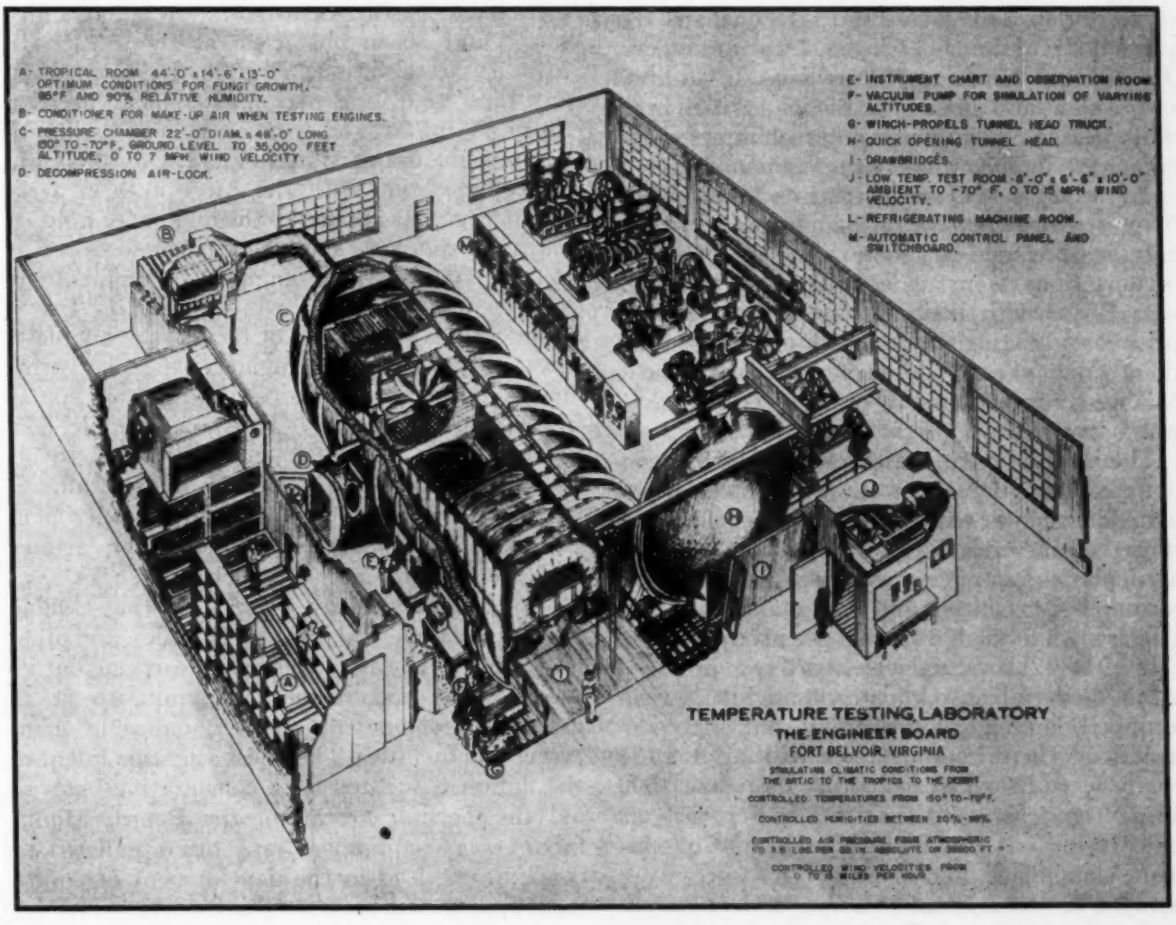

A- TROPICAL ROOM 44'-0" x 14'-6" x 13'-0"
OPTIMUM CONDITIONS FOR FUNGI GROWTH.
85°F AND 90% RELATIVE HUMIDITY.
B- CONDITIONER FOR MAKE-UP AIR WHEN TESTING ENGINES.
C- PRESSURE CHAMBER 22'-0" DIAM. x 46'-0" LONG
150° TO -70°F, GROUND LEVEL TO 35,000 FEET
ALTITUDE, 0 TO 7 MPH WIND VELOCITY.
D- DECOMPRESSION AIR-LOCK.
E- INSTRUMENT CHART AND OBSERVATION ROOM.
F- VACUUM PUMP FOR SIMULATION OF VARYING ALTITUDES.
G- WINCH-PROPELS TUNNEL HEAD TRUCK.
H- QUICK OPENING TUNNEL HEAD.
I- DRAWBRIDGES.
J- LOW TEMP. TEST ROOM 8'-0" x 6'-6" x 10'-0"
AMBIENT TO -70° F, 0 TO 15 MPH WIND
VELOCITY.
L- REFRIGERATING MACHINE ROOM.
M- AUTOMATIC CONTROL PANEL AND
SWITCHBOARD.
TEMPERATURE TESTING LABORATORY
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
SIMULATING CLIMATIC CONDITIONS FROM
THE ARTIC TO THE TROPICS TO THE DESERT
CONTROLLED TEMPERATURES FROM 150° TO -70°F.
CONTROLLED HUMIDITIES BETWEEN 20%-95%
CONTROLLED AIR PRESSURE FROM ATMOSPHERIC
TO 3.5 LBS. PER SQ. IN. ABSOLUTE OR 35000 FT.
CONTROLLED WIND VELOCITIES FROM
0 TO 15 MILES PER HOUR

FIG. 3. Temperature testing laboratory of The Engineer Board.

FIG. 4. Engine Laboratory, The Engineer Board, Fort Belvoir.

welcomed and given careful consideration in the correction of deficiencies and in the improvement of existing equipment and the development of new equipment.

In 1933, the Engineer Board was composed of seven officers, two of whom served full time on Board duties, and a limited civilian staff. As late as 1939, the personnel consisted of only four full-time officers and 30 civilian employees. Wartime expansion resulted in a peak personnel strength of more than 240 officers and 1170 civilians. The present strength is 148 officers, 2 warrant officers, 251 enlisted men, and 783 civilians. In addition, over a thousand unassigned troops are used in the daily testing of equipment and techniques undergoing development. There are civilian experts in nearly every field of engineering endeavor. Many officers with extensive civilian technical experience in universities, laboratories, and research organizations, were made available to the Engineer Board with their entrance into the Army prior to and during the present conflict. Together, these civilians and military personnel form a balanced, competent staff of engineering and research experts.

The internal organization of the Board is continually changing to meet new problems presented by the war effort. When a phase of the war effort becomes relatively unimportant, or when particular development work is completed, the personnel is reduced and the manpower thus freed is made available to other essential activities.

In 1941–42, the Engineer Board was provided with a modern research plant, housed in 24 well-equipped buildings of steel frame and brick construction. These buildings, constituting 368,123 square feet of floor space, with more than 1000 acres of land, furnish the setting at Fort Belvoir for carrying out the Board's mission. Concealment, camouflage, and dispersion measures were included in the original planning and construction of the entire area. Full advantage was taken of natural cover afforded by trees and topography. The low buildings, with their dark brick walls and flat, graveled roofs without parapets, were well dispersed in the area; and the roadways, held to a maximum width of 18 feet, were laid down in an irregular pattern. Today, the offices, laboratories, and shops of the Engineer Board provide an outstanding example of the concealment attained by careful utilization of natural cover and terrain.

In addition to the development work carried out at Fort Belvoir, the Engineer Board has a number of field installations which are set up to accomplish necessary test and development work and which operate as long as needed and are then dissolved. These installations are located in parts of the country where climatic or other conditions are specially suitable for the conduct of certain types of tests. Thus at present there are Board test branches near Yuma, Arizona, for the development of floating bridge equipage and other special equipment; at Fort Pierce, Florida, in cooperation with the Joint Army-Navy Experimental and Testing Board, for overcoming underwater and beach obstacles; at the A. P. Hill Military Reservation, Virginia, for overcoming anti-tank and anti-personnel mines; at Fort Story, Virginia, for test of water distillation equipment; and at Wright Field, Dayton, Ohio, for collaboration with the Air Forces in aerial photography as applied to the making of military maps. In the past, special branches were set up to test and develop engineer equipment for desert, mountain, and winter warfare. Use is made wherever possible of facilities available to the network of District Engineer Offices and other field agencies of the Corps of Engineers spread throughout the country. Thus, for example, considerable test work, particularly related to behavior of airplane landing mats under traffic, is accomplished at the U. S. Waterway Experiment Station, at Vicksburg, Mississippi, an agency well prepared to carry out such work.

The Engineer Board utilizes existing civilian agencies, commercial research facilities, and other Government research agencies in carrying out its development and research program, so as to expedite development and economize in manpower and facilities. The finest scientific talent of the nation is utilized on a consultative basis to aid the Technical Staff of the Board. Manufacturers of equipment are often enlisted to cooperate or lead in the development of equipment appropriate to them. The Board by contract utilizes laboratory facilities of the large industrial

manufacturing companies, as well as research departments of various colleges and universities throughout the country, to aid in the solution of its problems. The National Bureau of Standards, the Naval Research Laboratory, the National Defense Research Committee, Aberdeen Proving Grounds of the Ordnance Department, the Army Signal Corps, the Chemical Warfare Service, the Public Roads Administration, Forest Service, and other agencies of the Government assist the Board in carrying out certain phases of its work.

FACILITIES FOR RESEARCH

Reflecting the variety of Engineer tasks and equipment and the global aspects of World War II are the present research facilities of the Corps of Engineers and the fields of research covered by the various branches of the Engineer Board. The research facilities, mainly concentrated at Fort Belvoir, but including a number of field stations, as previously stated, in order to obtain specific climatic and natural conditions, provide the Technical Staff with the means of studying almost any problem in engineering, physics, and design; and of checking the operation of equipment under climatic conditions found anywhere in the world.

The Temperature Testing Laboratory provides climatic conditions from the Arctic to the Tropics to the desert to the substratosphere. A tropical room, with its constant temperature, high relative humidity, and more than 30 types of fungus organisms permits exposure of equipment to the corrosive and rot-inducing conditions of the Pacific Theaters of War.

Study of the physical and chemical characteristics of materials used in Engineer equipment, the control and determination of color, the testing of materials, and the formulation of specifications for materials such as synthetic rubber, coated fabrics, plastics, and protective coatings, are conducted in the Materials Laboratory. Here, also, are devised methods of treatment against the rapid deterioration characteristic of the tropics—work so important in the struggle with Japan.

There is a fully-equipped Electrical Laboratory with facilities for the study of the application of electricity, electronics, radiation, and optics to Engineer equipment; and an Electrical Testing Laboratory for the study and development of electrical power equipment, electric motors, and allied electric equipment.

Continual improvement and development of searchlights and searchlight mirrors are carried on in the Searchlight Laboratory and the Reflector Research Laboratory, which are specifically designed and equipped for such work.

The Water Supply Laboratory, composed of a chemical and bacteriological laboratory and a hydraulics laboratory, is equipped for chemical and bacteriological work, including the efficacy of chemicals and processes employed in water purification and supply in the field, the physical testing of water supply mechanical equipment, and hydraulic studies. A water distillation test station is maintained at Fort Story, Virginia, on the Atlantic Ocean, for the determination of the characteristics of water distillation units, such as the direct oil-fueled type and the more recent thermo-compression type, while operating with sea water. Development of high capacity, high head deep well pumps for small diameter wells is conducted by the Board at a field station at Thermal, California. The principal test well, accommodating pumps up to $5\frac{5}{8}$ inches in diameter, will permit pump settings as deep as 850 feet; and pumping levels may be accurately controlled between the ground surface and 850 feet below.

The Engine Laboratory at Fort Belvoir is specially provided with power absorption equipment and instrumentation for studying engine characteristics and performance leading to the selection, adaptation, and utilization of internal combustion engines in equipment being developed for field use.

A small airfield and a railroad at Fort Belvoir provide means of studying engineering problems incident to the construction, maintenance, and operation of those two transportation facilities. Near the airfield, roads varying from smooth concrete highways to a severe "Billy Goat" route are available for tests of road transportation equipment.

The shops and service laboratories of the Engineer Board are fully equipped to build small precision models or full-size units of Engineer equipment ranging up to large bridging equipment, and to provide such visual aids as may be required for technical study. Facilities also exist for the preparation of topographic models, relief maps, and terrain models. The principal shops and service laboratories are listed below:

- Machine Shop
- Blacksmith and Forge Shop
- Welding Shop
- Sheet Metal Shop
- Foundry
- Motion Picture Laboratory
- Woodworking and Pattern Shop
- Canvas Shop
- Paint Shop
- Model Shop
- Photographic and Map Reproduction Laboratory

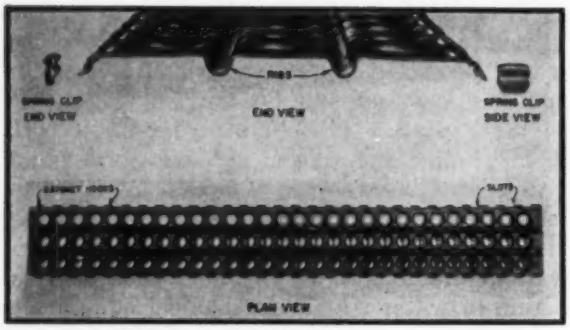


FIG. 5. Steel pierced plank for use as airplane landing mats.

TYPICAL RESEARCH PROJECTS

Directly stemming from the tasks of the Engineer soldier is the wide range of equipment, material, and techniques undergoing research by the Corps of Engineers. A project of first importance at the present time concerns methods and devices for the detection of land mines and the clearance of mine fields. The Demolitions Branch of the Engineer Board maintains a field station of some 5000 acres of isolated and varied terrain, a portion of the A. P. Hill Military Reservation, southeast of Fredericksburg, Virginia, for the study of the problems associated with the passage of anti-tank and anti-personnel mine fields by demolition methods. This area is also utilized by another branch of the Board for tests of newly-developed devices.

Another 500-acre reservation near Fort Belvoir is used for development and test of various demolition equipment and techniques, including comparative tests of explosives, trials of new uses of explosives, and tests of commercial demolitions developments.

At Fort Pierce, Florida, a section of the coastline is utilized for the study of methods of neutralizing and permitting passage of beach and underwater obstacles. In cooperation with the Joint Army-Navy Experimental and Testing Board at the same location, realistic tests have been conducted against full-scale reproductions of enemy obstacles erected on the site, as well as against natural obstacles to landing operations.

A major activity of the Engineer soldier in the European Theater of Operations has been concerned with bridging operations. Consequently, a large amount of research is devoted to the passage of water barriers, ravines, and ditches. Research on floating and fixed bridges, mobile self-launching bridges, footbridges, pontons, storm boats, outboard motors, air boats, propulsion units, and similar equipment, falls in this category. For tests of such equipment, in addition to the Pontoon Basin at the Engineer Board, facilities are maintained on the Colorado River, at Imperial Dam, near Yuma, Arizona, to permit test operations in controlled water velocities up to $10\frac{1}{2}$ feet per second with a minimum of interference from weather. One large job handled by the Engineer Board was the conversion of British bridge designs to the use of American structural members to permit prefabrication in the United States. Also, special semi-permanent bridges are designed for specific locations on lines of communications, before occupation of the area by our troops, in anticipation of the destruction of present bridges by our bombers or enemy action. Aerial tramways and other equipment for mountain and winter warfare have been developed.

Petroleum distribution equipment, which includes the portable pipelines used so effectively to supply fuel from the beaches of Normandy during the drive of the American Armies through France to Germany, centrifugal and reciprocating pumping units, petroleum storage tanks, and accessory equipment is under constant study at the Engineer Board.

New instruments and techniques to simplify and make more efficient the work of the Engineer soldier in regard to surveying, mapping, and map reproduction are under study. These instruments include military theodolites, astrolabes, and similar equipment required in establishing and extending ground control, and aerial photographic equipment. A reconnaissance device, the odograph, developed by the Engineer Board in conjunction with manufacturers, which automatically plots the course of a moving vehicle, is now in use by the Armed Forces. This device may be used for rapidly mapping an area or as a navigational instrument.

The old baseball axiom of "what they can't see they can't hit" is applied to military operations by the art of camouflage and the use of deceptive devices—camouflage of installations, of gun positions, of moving vehicles, of individual soldiers. Research in camouflage materials and techniques has been long an important part of the investigations of the Engineer Board.

Perhaps the tasks of the Engineer soldier which require the greatest quantity of equipment and materials are those pertaining to construction—roads, railroads, airfields, ports, housing, hangars, and related facilities and structures. Heavy machines and equipment, such as power shovels,

bulldozers, ditchers, road graders, rollers, asphalt and soil aggregate mixing plants, concrete mixers, and rock crushers are needed in large quantities; and often the construction work must be performed in spite of enemy fire. The necessity for suitably-designed machinery, to meet the portability, mobility, and operational requirements of military operations in all climates and terrains of the world, imposed upon the Corps of Engineers the undertaking of a large development program. Heavy earth-moving and construction equipment had to be designed for ready disassembly into sections not exceeding 5000 pounds for transport by air, and new equipment permitting entire machines to be airborne, without disassembly, and used immediately on landing had to be developed.

The speed which military operations demand of construction activities, the non-availability of materials in various parts of the world, and the natural conditions which must be overcome, have resulted in extensive research in structures. Best examples of special purpose structures and structures for use under unusual climatic conditions, which were developed under the auspices of the Corps of Engineers, are lightweight, demountable combat hangars; a prefabricated portable magazine for use in Arctic regions; a prefabricated Arctic shelter for five men, which can be transported by aircraft or dogsled; standardized designs for elevated, pre-stressed concrete water storage tanks of 250,000 gallons, 500,000 gallons, 750,000 gallons, and 1,000,000 gallons capacity; standardized designs for concrete storage tanks for aviation gasoline; and prefabricated barracks and hospitals.

In 1940, engineers lacked experience in the construction of airfields for heavy airplanes and intensive traffic. Therefore, the Office of the Chief of Engineers, in close liaison with the Army Air Forces, undertook an extensive research program to develop the fundamental data and to establish a design procedure. To conduct investigations and to assemble and analyze data, three laboratories were established—a Flexible Pavement Laboratory, U. S. Waterway Experiment Station, Vicksburg, Mississippi; a Rigid Pavement Laboratory, Ohio River Division, Mariemont, Ohio; and a Frost Effects Laboratory, Boston District, Boston, Massachusetts. Specific investigations were undertaken from time to time by university and other laboratories. Many laboratory and field tests were conducted, including frost investigation covering a wide area

FIG. 6. Engineer troops laying steel pierced plank runway.

in the United States, impact studies based on actual airplane landings, a continuing survey of pavement failures, plate bearing tests, static load tests, accelerated traffic tests, and investigation of the stabilities of paving mixtures. Similar research was also conducted on pavements and materials capable of withstanding the heavy loads imposed by Armored Division traffic.

THE DEVELOPMENT OF ENGINEER EQUIPMENT

The basic concept of an equipment design originates in the needs, anticipated if possible, of the Army. General characteristics which are required to satisfy the military application are formulated by the probably using arm or service. These characteristics are transmitted through channels to the research agency of the War Department equipped to perform the development work required.

The genesis of an item of equipment and the way in which the research organization of the Corps of Engineers acts to develop the equipment is best illustrated by citing some case histories of development.

AIRPLANE LANDING MATS

The term "Airplane Landing Mat," as used by the Corps of Engineers, designates any portable device, in sections or panels, capable of field assembly to provide emergency surfacing and permit early use of airfield landing strips and taxiways. The need for landing mats was realized several years before the entry of the United States in the present war. The characteristics desirable in landing mats were established in terms such as bearing strength, speed of laying, ease of handling, camouflage possibilities, weight, portability, and ease of replacement and repair,

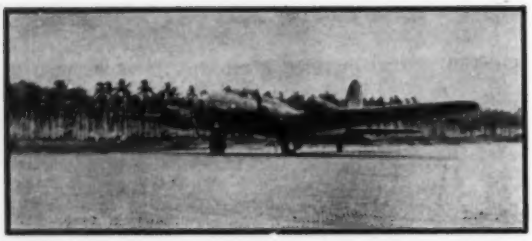


FIG. 7. Flying Fortress using steel pierced plank runway in South Pacific area.

with additional consideration given to cargo space requirements and rapid production possibilities.

In view of the urgency of the need, the Chief of Air Corps recommended that the development be directed toward supplying a usable mat at the earliest possible time, rather than toward reaching ultimate perfection at a later unknown date. In following this policy, the development was prosecuted in four successive steps: (a) Assembly and study of available data, foreign and domestic; (b) Laboratory tests of samples of prefabricated sections which were used commercially for other applications; (c) Small-scale engineering tests of various materials and mat designs; and (d) Full-scale service tests of the most promising materials and designs.

Early types of landing mats were considered unsatisfactory. The French bar-grid type mat, termed "Chevron Grid," which employed flat, zigzag bars on edge welded to flat runner bars, was structurally weak and had many jagged edges that caused severe tire wear. The British Sommerfeld Mat of wire mesh laced with $\frac{3}{8}$-inch round bars at 8-inch intervals, a development originating from attempts to strengthen the surfaces of the many turf fields used for light planes in England, was found to be of limited value except on turf and sand subgrades.

Engineering tests of commercially available materials, such as expanded metal concrete reinforcing, revealed that none was suitable for airplane landing mats. Therefore, the Engineer Board began the development of new designs, two of which—the plank type stamped from sheet steel, and the grid type fabricated by riveting or welding together standard steel bars—early showed promise of successfully meeting the characteristics desirable in landing mats. At this early stage, both types appeared to possess certain advantages and disadvantages. The plank type could be easily and rapidly produced in quantity from continuous strip mill stock by existing presses adapted to the purpose, but this type did not provide openings for aeration of the subgrade and for camouflage by means of seeding with grasses. The grid type with its large open areas would provide excellent subgrade aeration and good camouflage possibilities, but facilities for its production were limited. Hence, the development of both types was carried on simultaneously. Subsequently, the grid type was relegated to the status of a substitute, to be procured only in the event that sufficient quantities of the plank type were not available to fill requirements.

Based on information furnished by the Engineer Board, tentative designs for a steel plank type landing mat were submitted by several industrial companies during 1940 and 1941. The U. S. National Bureau of Standards and the research departments of the University of Michigan, Lehigh University, Catholic University, Carnegie Institute of Technology, and the manufacturers, assisted the Technical Staff of the Engineer Board in evaluating these and other designs and making laboratory tests on the mats. These studies, in conjunction with engineering field tests conducted with the cooperation of the Army Air Forces, led to many improvements in the design.

The type of steel plank adopted was 10 feet long with a 15-inch laying width. Longitudinal depressions, called ribs, gave the plank strength. The most difficult problem was to design a device permitting rapid connection of the planks to form a mat with sufficient strength to withstand the shocks and stresses produced by heavy bombers. This problem was overcome by a hook and slot arrangement, with alternate rows of planks having hooks or slots along both sides. Later, the hooks and slots were placed on both sides of all planks, which eliminated the need for two plank types. The planks were locked together by driving a few special spring clips in the slots back of the engaging hooks. This arrangement provided a strong connector which permitted rapid assembly of the mat in the field. To minimize skidding of aircraft and to increase transverse stiffness of the mat, various forms of embossing were tried between the ribs. In an effort more easily to camouflage a field of these ribbed planks, holes were punched between the ribs to provide for the sowing of grasses. These holes, flanged downward, also increased the transverse stiffness of the mat, improved its nonskid characteristics, considerably reduced its weight, and provided for aeration of the subgrade. This type of landing mat, termed "steel pierced

plank," was accepted as suitable for procurement and considerable quantities were purchased for war reserve and advance bases before December 7, 1941.

With the tremendous expansion in the number of airfields in the theaters of operations and the emphasis on heavy bombers, a rehabilitation plant for reclaiming landing mats deformed under traffic was developed to minimize production and shipping requirements. With this rehabilitation plant, approximately 90 percent of damaged landing mat is reclaimed for future use.

Studies of pierced steel plank landing mats are continuing, in order to improve performance, reduce weight and steel consumption, and to eliminate loose parts. Also, a landing mat of aluminum alloy, pierced plank design, equal in performance to the steel pierced plank mat, is being procured to meet the need for lightweight equipment for rapid transport, including airborne operations. For use in areas where large quantities of lumber are readily available, a wood type landing mat has been designed which permits rapid field fabrication and assembly.

Airplane landing mat was available to the Engineer soldier at the beginning of the present war. This mat has proven its worth in varying conditions of climate and terrain in many parts of the world. Soon after Pearl Harbor, it was used to provide urgently needed runways that could not have been built by conventional construction methods in time to meet the military requirements. It has demonstrated thoroughly the foresight and sound judgment of those who initiated this development. Today, it is used not only for surfacing airfield runways and taxiways, but for the construction of expedient roadways on beaches and in swamp areas; for parking areas for vehicles; as flooring for footbridges, machine shops, ammunition dumps, and tents; and as retaining walls, revetments, and footwalks.

MILITARY OXYGEN PLANTS

In military operations, large quantities of oxygen are required for breathing by aircraft crews at high altitudes, for medical therapy, and for use in cutting, welding, and salvage work. Foreign sources of oxygen were inadequate to supply possible demands in the field. An estimate of military oxygen requirements, available containers, and transport facilities revealed the impracticability of supplying adequate quantities to the fighting fronts in high pressure cylinders and the impossibility of returning empty cylinders. Therefore, immediate steps had to be taken to provide a military plant capable of producing sufficient quantities of oxygen at the place of use.

FIG. 8. Oxygen generating plant. This mobile plant is capable of producing, from air, 500 cubic feet per hour of 99.5 percent pure gaseous oxygen. The road weight of the semi-trailer and plant is 36,000 pounds

The aspects of global war, the large distances involved, the swiftly moving and often isolated battle areas, the possibility of bombing large stationary plants out of production, and the long hauls involved in supplying oxygen from fixed plants, dictated that a military oxygen supply plant have the following characteristics: (a) All facilities incorporated in one unit. (b) Good mobility over roads. (c) Operating qualities suitable for climatic conditions normal in any theater of operations. (d) Units sufficiently small to permit flexibility in use and dispersion of equipment in the field. (e) Simplicity in operation. (f) A high quality product to meet specific field applications. (g) Minimum weight consistent with performance.

The initial development was directed toward producing a small capacity, mobile unit based on design principles of commercial plants but incorporating the desirable characteristics for military use.

With the cooperation of the Army Air Forces and manufacturers of commercial oxygen processing equipment, the Corps of Engineers placed mobile oxygen supply plants in the field in the summer of 1943. This plant is a semi-trailer-mounted mechanical unit producing gaseous oxygen, based on the Claude and Linde cycles for oxygen production. The plant can produce from air 500 cubic feet of 99.5 percent pure gaseous oxygen per hour and is capable of charging this quantity of oxygen into high pressure cylinders

at 2200 pounds per square inch at 70°F. The power source is a 75-horsepower gasoline engine which drives five air compressors, each with a capacity of 1250 cubic feet per hour, and one oxygen compressor. The air drying and cleaning is accomplished at 900 pounds per square inch by the use of walnut-size potassium hydroxide and silicon dioxide. Refrigeration is accomplished by a one-horsepower vertical reciprocating expander operating between 900 pounds per square inch and 8 pounds per square inch, in combination with the throttling of air between the same pressures. The fractionation system consists of a single rectification column equipped with bubble cap trays.

Research subsequent to the placement of the above unit in the field has been directed toward a reduction in weight and size of oxygen producing units with higher capacity and simpler operation, the improvement of commercial oxygen supply equipment and its adaptation to military applications, and the development of new methods and equipment for producing oxygen.

In this program, which has extended up to the present time, both mechanical and chemical systems for the production of oxygen were studied and much experimental work was done thereon. The most promising of the numerous regenerative chemicals were studied; however, their potentialities did not materialize, and chemical systems were discarded in favor of the development of more efficient mechanical systems.

Mobile oxygen plants are now being used on every fighting front by Engineer soldiers organized as Engineer Gas Generating Units to supply oxygen to the Army and the Navy. The lives of fighting men in the Superfortresses over Japan, in the bombers and fighters which are destroying German war potential, of the wounded in the jungle, in the Italian mountains, and along the borders of Germany, are dependent on oxygen provided by the Engineer soldier from his mobile plants.

The foregoing describes the research activities of the Corps of Engineers during the present war. This war is a scientific war, a technical war, an Engineer's war. It begins in the research laboratories and ends with the application of superior equipment against the enemy on the battlefield. How well research has done its job, how well the Engineer soldier has been equipped in so short a time with the efficient instruments required for his job, may be judged by the progress of our forces against a clever, determined enemy in spite of his long head start and the years in which he had been planning and preparing for war. It is realized by the Corps of Engineers that research and development is an essential phase of modern warfare and that a lasting peace can be assured only by their continuance in the coming years so that no nation will be encouraged to attack us because of technological unpreparedness on our part.

The Research Program of the Office of the Surgeon General, U. S. Army

BY LT. COLONEL LEON H. WARREN

Office of the Surgeon General, Washington, D. C.

LT. COLONEL LEON H. WARREN.

ONE of the most important factors contributing to the excellent record of the Medical Department of the Army during this war has been the emphasis placed by the Surgeon General on the necessity for research in all fields of medicine, and the comprehensive research program which has been developed by and for the Medical Department. This program, carried on both by military and civilian scientists, has produced a wealth of new fundamental knowledge resulting in more effective methods for the care of the wounded and the prevention and treatment of many of the diseases which afflict troops.

The Medical Department of the Army has a long tradition of research. The investigations of William Beaumont on gastric physiology; Sternberg in bacteriology; Walter Reed on yellow fever; Strong, Ashford, and Craig on tropical diseases; Russell on typhoid fever; Darnall on the chlorination of water; and those of many others have contributed materially to the health and welfare, not only of our armed forces, but of the nation as a whole.

When war became imminent in 1939 the Surgeon General of the Army, recognizing the importance of scientific investigation to the fulfillment of the Medical Department's mission, inaugurated and threw the full influence of his office behind a greatly expanded program of medical research. This program has included investigations which may be divided into three categories, namely, investigative projects conducted in Army laboratories and field installations, those conducted in civilian institutions under Army contracts negotiated through the Office of the Surgeon General, and those conducted for the Army in civilian institutions under contract with the Office of Scientific Research and Development.

The research activities of the Surgeon General's Office have been coordinated with appropriate divisions of the Office of Scientific Research and Development, the Committee on Medical Research, United States of America Typhus Commission, research establishments of the Army, Navy, and Public Health Services, Governmental Departments, Scientific societies, and a large number of individuals. Every effort has been made to avoid undesirable duplication. The Army has confined its investigations to those problems which it could study most effectively and has utilized the efforts of civilian investigators to the greatest possible extent.

The Chief of Preventive Medicine Service, SGO, is a member of the Committee on Medical Research, Office of Scientific Research and Development. The Chief, Research Coordination Branch, Technical Division, Operations Service is a member of the National Research Council, representing the War Department in the Division of Medical Sciences.

RESEARCH PROJECTS IN ARMY LABORATORIES

The research work carried on within the Army under the direct supervision of the Surgeon General has covered a wide range of subjects. The diagnosis, prevention, and treatment of various diseases, including typhoid, dysentery, typhus, and syphilis, have been studied at the Army Medical Department Professional Service Schools in Washington, as have certain veterinary problems. At the Armored Medical Research Laboratory, Fort Knox, Kentucky, studies have been conducted to determine methods of prevention of the effects on the soldier of gases, dusts, temperature, noise, fatigue, and other operational hazards of mechanized warfare. At the Army Industrial Hygiene Laboratory at the Johns Hopkins School of Hygiene and Public Health in Baltimore, Maryland, investigations have been made of hazards encountered in Army-owned and operated industrial plants. In the Institute of Pathology at the Army Medical Museum in Washington, research has been undertaken in pathology, particularly in the pathology of infectious jaundice. Problems in veterinary

FIG. 1. Medical Department Professional Service Schools, Army Medical Center, Washington, D. C.

medicine have been studied at the Veterinary Research Laboratory, Quartermaster Remount Depot, Front Royal, Virginia. Items of field x-ray equipment have been developed by the Army School of Roentgenology, Memphis, Tennessee. Work on the design, modification, and development of medical field equipment has been carried out at the Medical Department Equipment Laboratory, Carlisle Barracks, Pennsylvania, and similar types of technological studies on the packaging of medical items have been made at the Army Medical Purchasing Office in New York City. Nutritional problems have been investigated in collaboration with the Office of The Quartermaster General, and problems related to gas warfare in cooperation with the Chemical Warfare Service. Service Command Laboratories in this country, and General and Army Laboratories abroad, have also engaged in research on a limited scale but with satisfactory results.

The Research Coordination Branch of the Technical Division coordinates the research and development projects underway in seven of the Medical Department laboratories under authorization by the Research and Development Division of the Army Service Forces; periodically analyzes and reports progress in research and development; maintains statistical records; and submits fiscal estimates for research funds in the War Department budget. These laboratories are as follows:

Medical Department Professional Service Schools, Army Medical Center, Washington, D. C.

Although this is primarily a teaching institution (Fig. 1), its professional personnel is engaged part time in research relating to the diagnosis, prevention and treatment of diseases and wounds. These studies include the development of vaccines, sera, blood substitutes, and the improvement of medical and dental supplies and equipment with emphasis on problems pertaining to tropical medicine. Under a project initiated in 1908 the triple typhoid vaccine produced by the Army Medical Center has undergone constant improvement. A polyvalent dysentery vaccine now being developed shows considerable promise. An equine encephalomyelitis vaccine developed at this laboratory is undergoing further refinement. Through its work in conjunction with the Office of Scientific Research and Development, other governmental agencies, and private business firms, improved methods of packaging of blood plasma (Fig. 2) have been developed and surveillance of manufacturers' products has been maintained. Recently a set for the collection and administration of whole blood in the field was developed to meet demands for transfusions at the front. This has helped to make possible the air shipment of more than 1,500 pints of whole blood daily to the fighting fronts and has been a potent life-saving measure.

Medical Department Equipment Laboratory, Carlisle Barracks, Carlisle Pennsylvania

This laboratory has complete facilities for developing, constructing, and testing all medical equipment except instruments or machines such as surgical equipment or instruments and x-ray tubes and equipment. It is constantly working on the development of new items (particularly those suggested by officers in the field), improving present standard items, studying captured materiel, and devising means of using non-critical materials when substitution is necessary.

One of the outstanding developments of this laboratory has been the utilization of the standard 2½-ton 6-wheel drive chassis for the following series of special Medical Department vehicles:

(1) The surgical operating truck carries a complete surgical unit forward as far as the clearing station. It is equipped with its own tentage, gasoline-driven electric generator for operating lights, complete surgical equipment, operating tables, linens, blood plasma supplies, and every other necessary adjunct to surgery. Set up by accompanying personnel within a short time, it provides tent space for four surgeons to work simultaneously. In actual field use as many as eighty (80) operations in 24 hours have been performed with such a unit. Mobile operating teams, composed of two surgeons and two or

more technicians, accompany these units in the field.

(2) The dental operating truck is equipped with a conventional dental chair, electric drill, instrument cabinets, operating lamp, sterilizing and lavatory facilities, and gasoline-driven electric generator. A similar truck now in operation contains all necessary equipment and facilities for making dental prostheses in the field.

(3) The medical laboratory truck to facilitate the conduct of epidemiological and similar studies in the field and the optical repair unit for replacing lenses and repair of spectacles well forward in the combat zone have greatly extended the range and efficiency of medical care.

The Medical equipment pack was developed in this laboratory to give greater flexibility and more immediate availability of instruments, medicines, bandages, and other equipment of a battalion aid station which was formerly carried in heavy, cumbersome chests. This new pack enables the transportation of this equipment in uniform weight packs which can be carried on the backs of personnel. They have proven an invaluable adjunct to medical care in forward areas of the jungle through which not even mules can pass and in mountainous terrain which can be negotiated only on foot.

The Equipment Laboratory also develops adaptations to meet field conditions as they arise. One illustration is a carrier to fit the ¼-ton truck, better known as the jeep, to transport litter cases in forward areas where ambulances bog down. The first carriers were improvised on the spot from materials at hand. Later, instructions were published to aid in making this conversion. At present, standard carriers are supplied complete to the theaters of operations.

Armored Medical Research Laboratory, Fort Knox, Kentucky

Although tanks were used in World War I and some experience was gained in their use, the development of blitz warfare and the increased use of armor created many new problems for the Army Ground Forces (Fig. 3). The extensive use of new, high-powered, speedy, noisy, and fume-filled vehicles introduced new problems in physical adaptability, fatigue, reaction time, adjustment to extremes of temperature, and other physiological phenomena found in armored mechanised warfare. This laboratory, under the professional supervision of Preventive Medicine Service, is equipped to do experimentation of a medico-

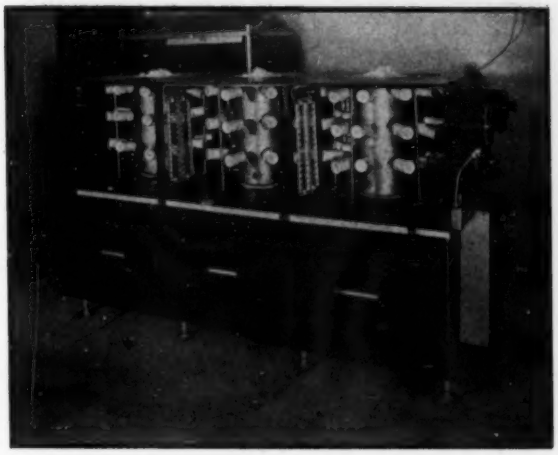


FIG. 2. Equipment for drying plasma.

physiological, technological type. The research so performed, which has resulted in the improvement of military equipment and in altering the characteristics of mechanized armored vehicles, has also been focused on training methods in order that the soldiers of the United States Army may be better fitted to carry out their military assignments under adverse climatic and environmental conditions. Among the various problems which have been considered on a field test basis in this program are: the influence of high temperatures upon the efficiency of personnel (Fig. 4), including the determination of water and salt requirements for desert operations; questions of vision, auditory damage, fatigue, and various exposures of tank crews; clothing and other needs for cold weather operations; and evaluation of various United States Army and foreign rations.

Army Industrial Hygiene Laboratory

This laboratory, also under the professional supervision of Preventive Medicine Service, participates in the Army industrial medical program by conducting plant studies, including investigations and surveys, of occupational hazards at Army-owned arsenals, depots, and other industrial installations; by furnishing assistance in the design of engineering control of harmful exposures; by training engineers; and by conducting research in the field of occupational hygiene. Chemical and medical investigations are made of the toxicity of particular materials found during the surveys and of those sent to it by other branches of the War Department. This latter function has gained considerably in importance as a result of the production of new chemical

FIG. 3. Armored Medical Research Laboratory, Fort Knox, Kentucky.

compounds and other agents designed to protect military equipment from deterioration. The laboratory, through patch-testing and analysis for toxic content of these agents, assists in the assembly of data upon the basis of which items of equipment are approved or rejected for use by the Army.

Army School of Roentgenology, Memphis, Tennessee

This institution is primarily a teaching installation, but its personnel also devote part time to research dealing with problems on various phases of radiology and x-ray equipment. At this institution the compact and highly efficient mobile x-ray field unit was developed early in the war. Other noteworthy items developed by this laboratory include the x-ray bi-plane marker and reorientating device; fluoroscopic field unit; and x-ray field table unit.

Army Veterinary Laboratory, Quartermaster Remount Depot, Front Royal, Virginia

This laboratory conducts research in problems of veterinary medicine. The range of its activities parallels that of research in human diseases and consists of investigation of improved means for the diagnosis, prevention, and treatment of diseases in animals (Fig. 5). This laboratory has succeeded in immunizing colts against equine influenza by infecting them with a mild form of the disease and is continuing investigations to overcome the various difficulties which lie in the way of an effective immunization procedure for field use. In a controlled study on equine periodic ophthalmia, this institution has found that in a group of normal horses on a low riboflavin diet a considerable number have developed symptoms of this disease. In another group of animals fed on garrison ration supplemented with riboflavin, no new cases of iridocyclitis have appeared since the supplementation was started one year ago.

Medical Nutrition Laboratory, Chicago, Illinois

The Medical Nutrition Laboratory, formerly the Nutrition Laboratory of the Army Medical School, has recently been established with professional direction by Preventive Medicine Service and is in process of construction at the Quartermaster General Depot, Chicago, Illinois, adjacent to the Subsistence Laboratory of The Quartermaster General's Office. The function of this laboratory is the study of problems of human nutrition with emphasis on these problems as they apply to the nutrition of the Army. The subject of one such investigation is the symptomatology of deficiency diseases. A project has been initiated to define the clinical syndromes of the lesser known vitamin deficiencies involving biotin, folic acid, pantothenic acid, and pyridoxine.

RESEARCH PROJECTS IN OTHER ARMY INSTALLATIONS

In addition to projects in the formal programs of the Army Epidemiological Board and Medical Department laboratories, many investigations financed by specific allotment of Army research funds are conducted at various hospitals and other field installations of the Medical Department.

Certain projects for which the Army research and development laboratories had no special facilities, or in which urgency indicated central administration, were conducted by the various divisions of the Office of the Surgeon General. A portable optical unit contained in two Medical Department chests was developed by this office and the Army Medical Purchasing Office in order to enable emergency limited repairs and replacements in the Army spectacle program in the field. The gas mask eyeglass to replace the unsatisfactory gas mask spectacles was developed by the Surgeon General's Office, utilizing the facilities of test subjects in a division undergoing training at a nearby Army post. The individual jungle medical kit providing first aid and emergency medical supplies for jungle troops was developed by this office in cooperation with other technical services in response to an urgent request from a theater of operations. A study of the stability of drugs and supplies at various temperatures was

accomplished by the American Pharmaceutical Association at the request of this office. The petrolatum gauze dressing for field treatment of burns was developed by the laboratories of a commercial concern under contract with this office.

The Development Branch of the Technical Division initiates action and coordinates development of medical items with other services of the Army. This technological research has resulted in the development of the following:

(1) Ambulances—coordinated with the Ordnance Department.
(2) Hospital railway cars—coordinated with the Transportation Corps.
(3) Photographic and projection equipment—coordinated with the Signal Corps.
(4) Head wound gas masks—coordinated with the Chemical Warfare Service.
(5) Oxygen therapy equipment—coordinated with the Chemical Warfare Service.
(6) Kits for testing gas contamination of food and water—coordinated with the Chemical Warfare Service.
(7) Power Equipment—coordinated with the Corps of Engineers.
(8) Water filtration equipment—coordinated with the Corps of Engineers.
(9) Special refrigerators—coordinated with the Quartermaster Corps.
(10) Clothing—coordinated with the Quartermaster Corps.

RESEARCH PROJECTS IN CIVILIAN LABORATORIES UNDER ARMY CONTRACT

Board for the Investigation and Control of Influenza and Other Epidemic Diseases in the Army (Army Epidemiological Board)

The organization of the board consists of a central board of seven (7) members and of ten (10) commissions with membership including approximately 100 civilian consultants to the Secretary of War who are experts in their special fields. The names of the commissions are as follows:

Commission on Acute Respiratory Diseases
Commission on Air-borne Infections
Commission on Epidemiological Survey
Commission on Hemolytic Streptococcal Infections
Commission on Influenza
Commission on Measles and Mumps
Commission on Meningococcal Meningitis
Commission on Neurotropic Virus Diseases
Commission on Pneumonia
Commission on Tropical Diseases

The fields of activity are indicated by the names of these commissions but the designations

FIG. 4. Tank in hot room, Armored Medical Research Laboratory.

are not interpreted so strictly as to prevent collaboration between commissions for work on a problem of common interest and importance to the Surgeon General and for the utilization of the talents of the consultants on any medical research problem in the field of infectious diseases that concerns the army.

The board and commissions, organically a part of the Office of the Surgeon General, are administered by the Preventive Medicine Service of this office. The consultants serve on a part time basis and are normally stationed at their home institutions. They are called to duty under orders issued through the Office of the Surgeon General, and their services are utilized in the field from time to time. These consultants have worked in camps and posts in the continental United States. They have also served abroad in investigations of infectious diseases among our troops in overseas theaters of operation. In addition to the civilian consultants, a group of Medical Department officers is attached to these commissions.

The commissions carry on long term investigations in the laboratories of the home institutions, particularly the institutions at which the directors of commissions reside. In addition, commissions carry out field investigations lasting from a few weeks to a year or more in Army installations. Except for the Respiratory Diseases Commission Laboratory at Fort Bragg, North Carolina, which is under the jurisdiction of the Surgeon General, the board and commissions do not own or operate any laboratories of their own. All of their work in laboratories in civilian universities, hospitals, and institutes is arranged through War Department research contracts. These contracts between the War Department

and civilian institutions have made it possible for the Army to secure very valuable services and facilities in the leading institutions in the country.

Actively engaged in medical research of importance to the Army since January 1941, these commissions have dealt with upwards of a hundred projects. Reports of their work have been made immediately available to the Surgeon General, and important actions for the welfare of the troops have been taken on the basis of these reports. Examples which might be cited are: studies of housing and living conditions in barracks; the control of respiratory diseases by limiting dust and bacterial content of the air in barracks through applications of oil to floors and bed clothing; development of a vaccine against influenza; basic work leading to the development of a vaccine against Japanese B encephalitis; studies giving information for improvement in the use of atabrine; the experimental production of atypical (virus) pneumonia; investigations on infectious hepatitis; assembly of information on the distribution of leprosy throughout the world; the control of hemolytic streptococcal infections; and the investigations of rheumatic fever.

These examples are offered partly to give an indication of the accomplishments which have been achieved by the research activities of this board, but primarily to call attention to it as a successful cooperative enterprise between the Office of the Surgeon General of the Army and the leading civilian institutions of the country. It has exemplified the fact that effective medical research can be done through an Army organization in which both Medical Department officers and civilians are engaged, and in which resources of great civilian institutions are brought to the support of the Army's program for medical research in this field. The board and commissions testify to the early appreciation by the Surgeon General of the fact that both competent military personnel and competent civilians are necessary to meet the needs for research from which new and increasingly beneficial information is drawn —beneficial both to the Armed Forces and for the advancement of science.

ARMY RESEARCH PROJECTS DEVELOPED BY CIVILIAN AGENCIES UNDER OSRD CONTRACTS

Realizing the need for more extensive investigative work than could be carried on within the Army, the Surgeon General has taken full advantage of the splendid resources made available through various civilian scientific agencies. The civilian response and the results obtained during this war afford an inspiring example of what can be accomplished through a well organized, coordinated national research program. Since 1940, at the request of the Surgeon General, the National Research Council has appointed a large group of committees under the direction of Doctor Lewis H. Weed to advise the armed forces concerning various medical problems. Since 1941 the Committee on Medical Research of the Office of Scientific Research and Development under Doctor A. Newton Richards has organized and supported numerous investigations which have been carried out by civilian workers in the scientific institutions of the country.

Through this great organization practically all of the medical investigative resources and research workers of the country have been mobilized, to assist the armed forces. The new knowledge thus made available has been applied immediately in the field. In the research undertaken by this organization, three outstanding contributions are: the development of the blood substitutes, including plasma; the development of penicillin from the status of a laboratory curiosity to its present position as an important life-saving therapeutic agent; and the development of new insect repellents and insecticides, especially DDT, which have substantially removed the hazard of typhus fever and have afforded effective weapons against malaria and other insect-borne diseases.

The penicillin program is an example of an instance in which the expenditure of Army research and development funds was used to expedite the making available to military personnel of therapeutic benefits vastly beyond those previously available. Expenditure of funds was not the only contribution of the Army Medical Department to the present high development of penicillin therapy, but it was a major one, and without this financial support exploitation of the potentialities of penicillin would have been delayed for many months, if not years.

In May 1943, penicillin was being produced in extremely limited quantities and in a rather crude form by a small number of commercial firms. It had been tested in a limited way by investigators working under contracts placed by the Office of Scientific Research and Development. At that time, the Army Medical Department established an aggressive program of research on penicillin. Contracts for substantial quantities of penicillin

were placed with all firms in a position to produce the drug and additional sources for its production were sought. Elaborate facilities for the clinical testing of penicillin were established initially in two Army General hospitals. Research teams were trained in these hospitals and similar studies were then initiated in an increasing number of hospitals. During the next five months, as a result of these studies, extensive and reliable data on the scope of the uses of penicillin, its dosage, and treatment plans were developed. Simultaneously, there was provided clinical evaluation of the quality of successive lots of penicillin received from each of the several producers. This information was transmitted freely to the producers, to the Food and Drug Administration, to the War Production Board, to the Committee on Medical Research of the Office of Scientific Research and Development, and to other agencies interested in the drug. These studies aided materially in guiding the improvement of the quality of penicillin as well as in establishing its place in medicine. Further Army support, administrative and technical as well as financial (through the placing of contracts for additional quantities of the drug), stimulated and assisted commercial firms to rapid improvement of production methods.

After the initial five months' period of controlled clinical research on penicillin, information on its uses and the volume of production were such that it was possible to standardize the drug and distribute it throughout the Army in ever increasing quantities. However, experimentation has continued both with reference to evaluation of penicillin in all types of infections and with reference to the development of new methods for administration and new treatment plans. There has been developed in an Army laboratory a means for suspending penicillin in oil which permits effective penicillin therapy by injections administered only three times each day instead of eight to twelve times as was formerly necessary. The military significance of this development is apparent from a consideration of the fact that it is now possible to cure gonorrhea by a single injection of penicillin without any loss of time from duty. Even without this latter development, penicillin had been established as one of the great advances in medicine and one of especial importance in military medical service. Not only has it afforded an effective means for treatment of some infections previously incurable, but it has replaced the sulfa drugs and other forms of therapy as the treatment of choice in many infections which, although not peculiar to military service, had previously caused both high morbidity and mortality. Its use in the treatment of venereal diseases has reduced to a small percentage time previously lost from duty because of these infections. These infections, although lacking the drama and possibly the sympathy accorded to diseases such as septicemia, pneumonia or meningitis, have been major factors in lowering the military effectiveness of a command. Penicillin has assumed an unparalleled position in the treatment of battle casualties. Its use in all except the most minor wounds has rapidly approached routine, with the administration often beginning within a few hours after a soldier is wounded. Final clinical apprasial of its total results in these cases will require much additional time, but evidence to date has indicated that it has reduced the incidence of serious wound infections and has permitted surgical closure and healing of wounds far sooner than would otherwise have been possible.

FIG. 5. Technicians performing laboratory studies of animal tissue, Army Veterinary Laboratory.

SUMMARY OF RESULTS

The Contribution of Wartime Research to the Control of Military Diseases

The sum total of all these wartime investigations, both within and outside the Army, represents an enormous contribution to military medicine, and thus, to the successful termination of the war. Within the short space of four years these joint researches in the laboratory and in the field have afforded greatly improved methods for the control of a number of diseases.

With the exception of the dysenteries, the gastro-intestinal diseases, formerly the scourge of

all armies, have been relatively unimportant in this war. All troops are immunized with improved vaccines against typhoid, the para-typhoids A and B, and cholera, and these diseases have been practically eliminated. Intensive research aimed at the production of an effective dysentery vaccine has not yet afforded such an agent, but this work is being continued.

The respiratory tract diseases were greatly feared at the beginning of this war, because of our unfortunate experience with influenza in World War I. Consequently, unusual emphasis has been placed on their investigation, and a great fund of new information has been made available. Diphtheria, measles, mumps, scarlet fever, and acute rheumatic fever have been much less common than in the last war, and the death rates have been negligible. Meningitis increased during the civilian outbreak last year, but the total prevalence is lower than in World War I. The case fatality which was 38 percent in the previous war has been less than 5 percent. Sulfadiazine has been employed as a prophylactic agent. The pneumonias, including all types, have also been less prevalent, although the newly recognized but rarely fatal primary atypical pneumonia has been fairly common. The total fatality for all types of pneumonia in World War I was about 24 percent compared with less than 1 percent in the present war. Two epidemics of mild influenza have occurred; one early in 1941, the other late in 1943. There were practically no complications or deaths. During the second outbreak the Army carried out an extensive vaccination experiment which indicated the protective action of a new vaccine containing virus A and B. This vaccine is now being manufactured and stored for future military use should it be required. Considered as a whole, the highest monthly mortality rate from respiratory diseases in this war has been about 1/500 of the highest monthly rate during 1918.

The highest monthly venereal disease rate reported during this war has been less than the lowest rate for the last war. Chemotherapeutic researches have provided new prophylactic and therapeutic agents, which not only have helped to prevent venereal disease, but have shortened the period required for treatment. At the beginning of the war there were 1200 days lost per year for every 1,000 men under arms, but during the first six months of 1944 this loss of time has been reduced to less than 400 days per thousand per annum. In 1940 twelve percent of our gonorrhea patients developed temporary disabling complications, but today less than one-half of one percent have such complications. Until recently, soldiers with syphilis required a minimum of six months for treatment; today, using penicillin, the treatment lasts only two weeks, and the results appear to be good.

The insect-borne diseases include many of the greatest military hazards of this war. As already indicated, great progress has been made in combating such infections. Malaria has been completely controlled among troops in the United States. In certain tropical theaters the rates were high early in the war but this situation has been corrected and effective malaria control is now being carried out throughout the Army. The improvement overseas has been due to a number of factors, including the new insect repellents and insecticides developed in cooperation with the Department of Agriculture and to the use of suppressive drugs. The spraying of DDT from airplanes for Anopheline control and the use of DDT residual sprays on buildings and tents are important recent improvements. Moreover, more than one million dollars is being spent on the search for more effective antimalarial drugs and promising leads have already been discovered.

As mentioned above, the menace of epidemic typhus fever to our Army has been substantially dispelled by the use of an improved vaccine and the development of DDT louse powder. Scrub typhus, which has occurred in a few places in New Guinea and in Burma with a mortality varying from 3 to 30 percent, can be controlled with dimethyl phthalate, supplemented by sanitary procedures. Other rickettsial diseases of this country including the mild murine typhus, and the dangerous Rocky Mountain Spotted fever, have caused no serious inconvenience.

An effective yellow fever vaccine developed by the International Health Division of the Rockefeller Foundation has been used to immunize all soldiers exposed to the hazard of that disease. There has been no yellow fever in our Army. Plague vaccine is supplied for use, if required, and plague has not occurred.

Dengue and sandfly fever have been annoying in certain regions, but both can be controlled with our new insecticides and repellents.

The Army Medical Research Board recently established in the Surgeon General's Office will coordinate all phases of Medical Department research with other staff agencies and components of the Army as well as with agencies outside the Army.

Research in the Military Planning Division, Quartermaster Corps

BY COLONEL GEORGES F. DORIOT

Director of the Military Planning Division, Office of Quartermaster General

RESEARCH in the Army Quartermaster Corps embraces and draws upon nearly all of the sciences, pure and applied; it serves, however, but one master—the protective needs of a huge army of fighting men engaged in global warfare.

Before 1940 military planning in the United States was based largely on theories of defense. The Quartermaster Corps, which is charged with the supply of food, clothing, shelter, and all general articles of equipment used by most of the services, did some experimentation, primarily at its four large procuring depots; on footwear, at Boston; on clothing and textiles, at Philadelphia; webbing, tentage, and mechanical items, at Jeffersonville; and subsistence, in Chicago. It was, however, for the usual single-area type of warfare.

After Pearl Harbor it became clear that the impending war would be fought on a world-wide basis. The Military Planning Division of the Office of The Quartermaster General initiated extensive research on the new requirements imposed by global warfare, and on July 31, 1942, all of its research activities were centralized under the direction of a new agency, the Research and Development Branch of the Military Planning Division.

This Branch has a far-reaching mission. It serves as a nerve center linking the needs of a far-flung Army with the capabilities of American industry. It brings to the solution of immediate problems the nation's outstanding resources of brains and mass production, and translates pressing needs into quick action that would normally take years of development. It learns from reports and from its observers at the front what the Army lacks, what are the shortcomings of its equipment, and tells industry what the Army needs. It defines the problems precisely, making clear what it seeks and why, guiding the experimentation and research through every step, and testing the finished product. It reaches into laboratories and industries and hitherto untapped resources and, from the hopper of American ingenuity draws forth for example, a new boot that can withstand the abrasive sands of the desert, a thin cloth that will repel water and resist fire, and many items of specialized equipment for which a nation at peace had had little need.

To accomplish this the Research and Development Branch has brought a new point of view to American research. Its dominant objective is functional utility. It has disproved commonplace notions about food, clothing, and shelter, and it has emphasized in the solution of problems in these everyday matters the methods of science and the scientists themselves. It has tended to infuse into industry, more than ever before, the spirit of science and the interdependence of its various separate disciplines. It has mobilized in industry an awareness to ways of meeting specialized, changing needs.

The Research and Development Branch is one of four branches in the Military Planning Division. The Operations Branch plots the role of Quartermaster units in the broad strategic and logistical plans of the War Department, and furnishes information on troops strengths. The Requirements Branch studies the supply requirements of the Army, usually for a year in advance, and fixes amounts and methods of distribution. The Machine Tabulating Branch, as its name implies, makes statistical analyses and computations for the Division at large. And the Research and Development Branch develops and standardizes the various items required.

This is obviously an oversimplification of the functions of the four branches; in actuality they operate interdependently as a team to plan the campaign by which the Quartermaster Corps accomplishes its mission of getting the right supplies to the right men at the right place at the right time.

As indicated by the accompanying chart, the Research and Development Branch is supervised by the Assistant Chief of Branch. Directly linked to him are the Director of Research and the Assistant for Military Characteristics. Through all the phases in the development of a new product, the assistant for Military Characteristics acts as a liaison with the Army and with Allied Nations military missions to assure that the

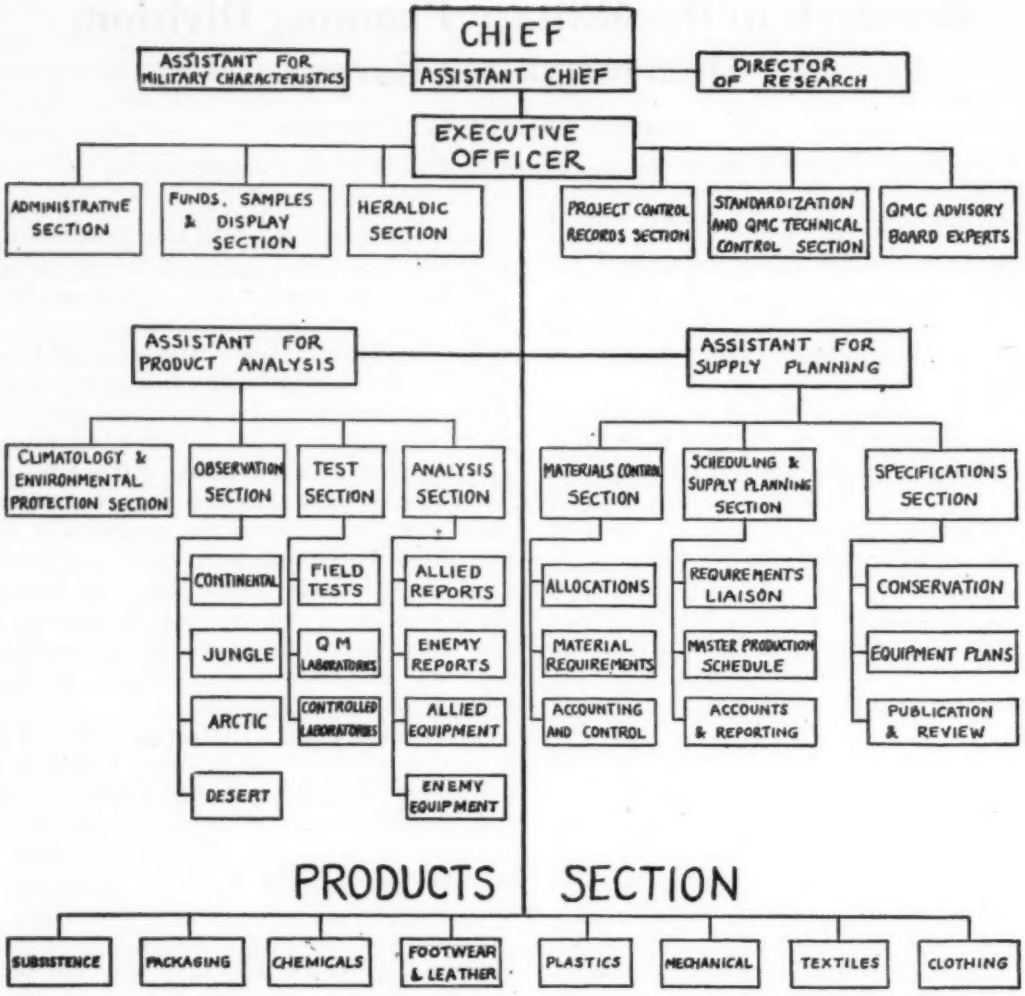


FIG. 1. Research and Development Branch of the Military Planning Division of the Office of the Quartermaster General.

product will satisfy military functional requirements.

Under the Assistant for Product Analysis are four sections. One collects scientific data about environmental facts in all parts of the world, another sends trained observers to the various theaters of operation to ascertain military needs, the third tests items of equipment during development and before adoption, and the fourth analyzes reports and studies equipment used by our allies or captured from the enemy. Taken collectively, it is this subdivision which furnishes the basis for research and development by eight Products Sections, each specializing in one class of related commodities.

Composed largely of experts drawn from industry, research agencies, and governmental bureaus, the Products Sections guide the solution of particular needs of our various arms and services from the seed of an idea through its development to the finished product. They undertake to point the way to industry in the actual research, collaborate in directing its progress, design improvements, make modifications in procedure for reasons of production or conservation of materials, write the specifications, prepare the final drawings, and prescribe tests which govern the acceptance or rejection of the products.

The three sections under the Assistant for Supply Planning supervise the development of the finished sample to the point where it is ready for standardized volume production, taking into account at all times the availability of materials and manufacturing facilities.

Research in the Quartermaster Corps repre-

sents a new point of view not only in attitude but in application as well. The Research and Development Branch, although it maintains extensive research laboratories at several procurement depots, cannot in the nature of things directly maintain laboratories adequate to carry out all of the research and development necessary for the responsibilities which it carries. The Quartermaster Corps handles some 6000 classes of supply and more than 71,000 individual items. If all of its research were to be centralized in one place it would need a veritable metropolis with a vast expanse of buildings, laboratories, and testing grounds as well as a huge force of workers.

Most of the research is conducted where it will do the greatest good in the shortest time—in industry itself. At present, 144 industrial laboratories are investigating problems posed by the Quartermaster Corps. In addition, 74 other agencies are carrying on research—29 colleges and universities, 16 private laboratories and consultants, 4 scientific foundations, 8 Government bureaus, and 7 professional societies.

Much of this research is performed on a contractual or purchase order basis. During 1944 the appropriation for outside research was well over $3,000,000. Many of the projects are set up in consultation with leading scientific and professional societies. Some of these cooperating agencies are the Office of Scientific Research Development, the National Defense Research Committee, the Office of Strategic Services, the Committee on Medical Research, the National Academy of Sciences, the National Research Council, and the Office of Production Research Development.

Industry in general, with true Americanism, has placed its laboratories and staffs at the disposal of the Office of The Quartermaster General. The effects of this great collaboration and cooperation, with but one focal point, the winning of the war, will have far-reaching peacetime benefits to both producer and consumer alike. The war-born necessity for research is resulting in better production methods of better materials which are being appreciated by both large and small manufacturers, and is the basis for a fuller appreciation of the benefits of research.

A considerable amount of the research and testing is conducted in laboratories controlled directly by the Research and Development Branch. The procurement depots at Chicago, Jeffersonville, and Philadelphia have large specialized research laboratories directed by the Research and Development Branch. At Lawrence, Massachusetts, the Quartermaster Corps maintains the Climatic Research Laboratory dedicated to all phases of study of the acute effects of environment on human physiological processes. Large testing laboratories are maintained also at the three depots mentioned above, with smaller laboratories at Boston, Jersey City, Charlotte, North Carolina, and several other cities.

Occupying extensive quarters on the sixth floor of the building of the Quartermaster Depot on Chicago's South Side, the Subsistence Research and Development Laboratory, studies problems ranging from taste acceptability and nutritive values of foods to the water-tightness, crash resistance, and insect resistance of packaging. Although the well-equipped, white-walled laboratory creates the usually scientific atmosphere indicative of the major activities of the laboratory, technicians can be observed in seemingly odd and surprising activities. Bakers pull loaves of bread from ovens and break them apart for study. Girls in white, mixing ingredients of a recipe, measure and weigh them minutely. Men immerse cases of rations in a sheet-iron tub full of water, drop whole crates of eggs from a ladder onto a concrete floor, and throw bricks at milk cans. In tropical and arctic test rooms food products are subjected to simulated jungle heat and dampness and to the freezing cold of arctic blizzards.

Food technologists in the laboratory are experts in nutrition, physiology, chemistry, bacteriology, engineering, physics, and other sciences. The extent of their facilities and equipment permits activities ranging from assembling experimental army rations for field tests to examining under a microscope the bacteria and fungi growing in various types of packages. They prepare scientifically the necessary specifications covering every detail of manufacture, setting the standards of quality of each food product used in the army diet. They inspect and evaluate foods submitted by manufacturers, testing their compliance with specifications, and constantly revising these specifications to keep abreast of progress achieved through research.

It was in the Subsistence Laboratory, which had been originally established a quarter of a century ago as a school for the training of mess and commissary personnel, that many of the feeding innovations and improvements of the present war were developed. These include the

FIG. 2. Rations developed at the Subsistence Research Laboratory of the Chicago Quartermaster Depot are given further tests in the laboratory of Dr. Anel Keys at the University of Minnesota, Minneapolis. A soldier from Fort Snelling, Minnesota, is shown walking on a treadmill under full pack after eating one of the experimental Army rations.

large-scale, successful uses being made now of boneless beef, dehydrated foods, and at least seven different types of rations made available in small, compact, moisture-proof packages.

On the sixth and seventh floors of the tower of the Philadelphia Quartermaster Depot is the Tropical Deterioration Research Laboratory with a staff of mycologists, soil bacteriologists, histologists, chemists, and assistants who devote their efforts to fundamental studies on the degradation of Quartermaster items caused by mildew, soil bacteria, sunlight, atmospheric oxygen, and moisture. Samples of materials from tropical theaters are carefully packed and sent to the laboratory. There cultures are made of the mycological and bacterial flora which are then separated until pure cultures are obtained and identified. The action of these organisms on cotton fibers, leather, and plastics is then studied. The war has provided opportunities for the collection of economically important fungi and soil bacteria from a wide group of little studied tropical regions. The Quartermaster has realized that such opportunities are rare and has laid the foundation for much far-sighted work in problems of tropical deterioration of equipment by isolating and preserving for present and future studies the great variety of fungi and bacteria which cause such serious damage to tentage, leather, and plastic materials under tropical conditions.

An exposure test center has been set up at Homestead Air Base, Florida, where exposure of tents under known and recorded conditions permits a direct interpretation of the meaning of the textile and chemical laboratory tests in terms of the functional life of the equipment. A similar program of exposure of samples of tentage materials is carried out in Panama. From both of these have come extensive series of mold and bacterial cultures and these have been compared with those obtained from the tropical theaters. These cultures provide the basis of further studies directed to the improvement of preventive measures to combat deterioration of equipment and supplies. This portion of the work is being carried on in the new Biological Laboratory of the Engineering Division of the Jeffersonville Quartermaster Depot where mycologists, chemists, physicists, bacteriologists, and engineers are working in close collaboration with industrial laboratories to translate the new fundamental knowledge rapidly into practical means for lengthening the life span of equipment under severe conditions.

Spinning and weaving—the making of textiles—is one of the oldest crafts known to man. Making use of the many types of textiles developed through the years, technicians of the Quartermaster Corps, with the aid of scientists in and out of the industry, developed new ways of constructing, finishing, and dyeing textiles, and created new water-repellent cloths through a special method of weaving.

Research and testing of textiles is presently largely divided between the depot laboratories at Jeffersonville, Indiana, and Philadelphia, Pennsylvania, the former specializing in heavy textiles such as duck and webbing, and the latter in clothing, coated fabrics, and clothing textiles. Physical and chemical and biological tests are made to determine the defects in fabrics, and full reports are passed on to manufacturers.

But whether carried on in the depots, numerous army installations, or university laboratories, research for the Quartermaster Corps is controlled and directed from the Research and Development Branch in Washington, D. C. Its staff of 84 Army officers and 626 civilian experts, technicians, and clerical personnel is the nucleus of a vast army of research workers in all parts of the country. Since its establishment in 1942 the Branch has conducted approximately 700 distinct projects, 194 in 1942; 208 in 1943, and 276 in 1944.

From inception to completion projects go through nine major steps. Problems arising in industry or in the Army must first be formally set up as a project and approved by the Requirements Division of the Army Service Forces. After the military characteristics of the article desired are formulated, the project is assigned to a research agency. The resulting item goes through a series of tests, must be subjected to a review and analysis, and following its standardization for military use, is submitted for final approval to the Quartermaster Corps Technical Committee. Specifications are then drawn up and it is ready for manufacture.

Through every phase of the development of a project the Director of Research serves as a guide and coordinator. He schedules and assigns projects to the various commodity sections, he supervises the research and testing laboratories in the depots, keeps in constant touch with cooperating agencies, and maintains a master record of progress on all the research activities of the Branch. In close collaboration with the Assistant for Military Characteristics he directs the research to its ultimate functional goal.

The Army learned many lessons from this war but one of the most outstanding was the absence of an almost elementary technical knowledge among the majority of personnel engaged in certain industries. Loose thinking predominated in the claims made for certain raw and converted materials. Experience demonstrated that only by a scientific approach could the Quartermaster Corps get the answers to a few simple questions it raised for example, about the thousands of articles of clothing it handles: What are the exact physiological reactions of a man wearing a certain garment in a given climate? How long will this garment hold up under rough use in the field? How much protection will it give against thorns, briars, mosquitoes, and the rigors of climate? What are the thermal insulation properties of the garment? What types of thin fabrics resist the attack of mosquitoes?

Accordingly, it began seeking the answers, and it is still doing so today in hundreds of laboratories and on its testing and proving grounds. In most instances the complete mosaic cannot be constructed without delving into a variety of arts and sciences. It involves an eclectic scientific method. Let us consider, for instance, some of the steps in developing correct clothing.

The physiological responses of men in certain garments to varying climates are measured in the Climatic Research Laboratory at Lawrence, Massachusetts. In the cold chamber, in which from one to thirty men may be tested at one time, temperatures can be adjusted and maintained at any point between 30°F and −70°F. Snow can be made by turning a switch. Atomizers provide the moisture that condenses as snow flakes in the freezing atmosphere. The atomizers in the wind tunnel can create a howling blizzard.

Just as snow can be obtained in the cold chamber, so can jungle or desert atmosphere be simulated in the hot chamber by increasing or decreasing the humidity. Temperatures can be regulated from 30°F up to 140°F. Rains of varying intensities, dropsize, temperature, and distribution can be produced and troughs of mud provided for marching. Both chambers are equipped with treadmills to measure fatigue of marching men.

Reactions of test subjects are recorded by the use of thermocouples, and radiometers which are attached to the body and wired to a recording potentiometer outside the chamber where the skin temperature at each thermocouple or radiometer is constantly shown. One thermocouple is worn internally by each man being tested to give body temperature for comparison with skin temperature. Frequent readings of the temperatures provide an accurate record of the insulation value of the clothing being studied and also indicate any approaching danger to the men from frostbite or from rising body temperatures. The expired breath of the men in the chambers is collected and chemically analyzed to determine the ratio of carbon dioxide to oxygen showing the men's rate of metabolism and the output of body heat.

Tests similar to those made at Lawrence have been made by such cooperating agencies as the Pierce Laboratories of Industrial Hygiene and the Harvard Fatigue Laboratory. Specialized phases of related problems have also been studied for the Quartermaster Corps by such institutions as the Laboratory of Physiological Hygiene at the University of Minnesota, and the departments of physiology at the University of Indiana and the University of Rochester.

To give authoritative information about the types of climate and environment which our fighting men are apt to encounter in various parts of the world, a climatology unit was set up in the Research and Development Branch in 1942. With a staff of professionally trained

FIG. 3. The "roof test," in which samples of every textile item being examined are exposed to sun, air, and other atmospheric conditions.

geographers, climatologists, cartographers, and map draftsmen, the unit charted the climates of the world on large-scale zone, climatic, and seasonal maps. They examine each article of clothing in relation to insulation, temperature, wind resistance, the use to which it is to be put, and the length of time it provides adequate protection. They know the thermal values of all garments individually and collectively. They consider the effects of radiation and solar heat, air movement, evaporation conduction, and many other principles and evaluate a garment on the basis of the physical requirements of the man who is to wear it, considering the environment in which it is to be used, and the extent to which it modifies the environment.

Thermal balance is important under all conditions. In order to define simply the thermal protection afforded, whether it is that of clothing or of the air within and around it, we use a unit which we have given the name, "clo." One clo is equivalent to the protection given by an ordinary suit of clothes which permits a man to sit at rest in still air at 70°F, and yet maintain thermal equilibrium: or expressed in terms of physical measurement, one clo is equivalent to the thermal insulation of $\frac{1}{4}$ inch of still air or of enough textile material to immobolize that air.

Approximately 4 clo is the maximum thickness which a soldier can wear and yet work efficiently, and 8 clo the maximum volume he can carry as sleeping gear; above 2 clo on the hands interferes seriously with the dexterity required. In still more realistic terms a man who is deficient 1 clo in an environment which demands the maximum thermal protection is losing heat or energy at a rate 25 percent faster than he can produce it when he is inactive.

A man properly clothed for a given temperature and for a given rate of activity will lose heat as fast as he produces it and no faster. If he is sleeping, he generates about 70 kilogram calories per hour; while standing guard he generates about 120 kilogram calories per hour; if he is carrying a pack, he generates 360. Unfortunately, we have not been able to put any one outfit on a man, which will give the right insulation at every level of activity or at all temperatures. And we have had much more success in developing clothing to keep a man warm in frigid climate than in designing garments to keep him cool and protected against his environment in torrid zones.

Since laboratory testing is of restricted value, field testing agencies throughout the country are used to determine the serviceability of clothing under the hardships of war. At these installations, field use is simulated in areas and under conditions such as those for which the clothing has been designed. At Camp Lee, Virginia, the Quartermaster Board, essentially a field-testing agency, conducts normal-usage and expedited usage tests of Quartermaster clothing and equipment. It has built a shoe track designed by geologists and containing the soils and surfaces of terrains likely to be encountered by American troops in the field. Soldiers testing clothing go through a "combat course" containing barbed wire, mud, trenches, revetments, wrecked buildings, and concrete tank traps through which they run, crawl, creep, and slide. Throughout, the goal is tested knowledge. The results of all tests are submitted to statistical analysis. This procedure has given very valuable information second only to actual combat performance records of the equipment.

In some instances the Quartermaster Corps has organized expeditions to obtain first-hand climatic and environmental conditions. In the summer of 1942 a force of 17 highly trained experts on mountain climbing, flying, and equipment related to these activities spent ten weeks amidst the storms, glaciers, and ice fields of Mt. McKinley, Alaska, highest peak on the North American continent. There all sorts of clothing and equipment were put to crucial tests in camps at elevations of 10,000 and 18,000

feet and in a climb to the very top of the 20,300-foot peak. Another expedition went down to Camp Indian Bay, Florida, in the summer of 1944 to study equipment under tropical conditions. In one test a field expedition sat absolutely still for one hour in jungle heat to determine how many mosquito bites would be incurred on the shoulders of men through different fabrics. The test resulted in much valuable information.

One of the first enterprises of the Research and Development Branch was the recruitment of some 225 outstanding specialists in various fields of industry and science to serve as a Quartermaster Corps Advisory Board. Made up of nationally known experts in such fields as nutrition, exploration, insulation, plastics, materials handling, tooling, refrigeration, and the individual industries and sciences, the Board makes it possible for research workers to call on the members for consultation and advice.

An enumeration of all the areas of science in which Quartermaster research has been conducted in this war would find hardly one untouched. As in science itself, there is no sharp delineation between the individual areas of research studied by the Branch. Our work, for the most part, necessitates a catholicity of approach and a correlation of the sciences. However, some of the scientific disciplines in which investigations are being carried on may be indicated:

Physics—Physical principles of fabric construction; underlying tensile and tear strengths and resistance to abrasion and degrees of thermal insulation; mechanism of adhesion and delamination in fabric laminates; thermal insulation of clothing in correlation with design, construction, heat condition, convection, air movement, moisture evaporation, temperature regulation, and metabolism.

Chemistry—Purification of individual water supplies; water repellent treatments for textiles; insect repellents and insecticides; flame and fire-proofing of fabrics; deleading of gasoline for special purposes; fungus-resistant treatments; synthetic detergents; soaps adapted to water of all degrees of hardness and to sea waters.

Human Physiology—physiology related to problems of activity and rest under all types of environmental stresses; human locomotion in relation to footgear; physiological aspects of nutrition in relation to health and activity of troops under environmental stresses and tactical restrictions.

FIG. 4. Extractors used in determining the percentage of sizing in materials, and the percentage of extractible matter, such as fats and oil, in woolen textiles.

Bacteriology—action of soil bacteria on leather, fabrics, paper, and plastics; preservation of foodstuffs; sterilization of individual water supply.

Geology—effect of different type of terrain and soils on durability of footwear; design of tent equipment for rocky, sandy, coral, and other types of soil.

Engineering—the design and development of mobile bakeries, laundries, refrigeration equipment and of airborne equipment of these types; engineering studies on the use of light alloys and substitute materials in equipment; the design and development of materials-handling equipment for all types of terrain and for beach landing operations.

Metallurgy—the development of inexpensive corrosion-resistant alloys; light alloys with increased hardness, corrosion resistance, and durability; surface treatment of light metals and alloys for corrosion resistance and camouflage.

Mechanics—design of tents to eliminate fabric stresses; application of monocoque construction to refrigeration equipment; development of lightweight gasoline engines for packboard transport; design of special-purpose hand tools and hand-operated equipment.

Nutrition—The formulation of menus providing the maximum of nutrition and acceptability under the wide range of geographic locations and environmental conditions presented by global warfare. The development of non-perishable foods of high acceptability and capable of withstanding extreme variations in climatic conditions.

FIG. 5. One of the most important characteristics of rope and cord is its tensile strength. Here an operator is testing the tensile strength of a piece of rope being analyzed in the laboratory of the Philadelphia Quartermaster Depot.

Entomology—the development of insect repellents, larvicides, and insecticides; design of insectproof storage and shipping containers;

Mycology—extensive fundamental studies and development of practical measures for the protection of fabrics, leather and plastics from attack by fungi.

Climatology—The determination of the exact climatic and geographic environment for each part of the globe, and man's physiological reactions when subjected to each of these. The establishment of fixed values to enable the Quartermaster Corps to provide, with scientific accuracy, clothing and equipment that will adequately protect troops in the wide range of climatic and geographic environments encountered in global warfare.

Much of the research and its results must, of course, remain confidential, but a glimpse at some of its principal developments will give an indication of how the collaboration between industry and science is helping to protect our soldiers against their environment.

CLOTHING

The use of pile for arctic inner garments; the establishment of the principle that layers of clothing give better protection against the cold than one bulky, heavy garment (this also makes possible interchangeability of garments from arctic to temperate zones); improvement of all materials and extensive use of substitute materials in footwear; the development of more than two dozen types of shoes specially designed for different environments; production of mosquito-proof tropical garments and a suit for protection against body lice in typhus-infested areas;

TEXTILES

Use of nylon in parachutes, mountain ropes, jungle hammocks, tents, ponchos, sleeping bags, shoelaces, and other items; the development of new laundering methods to retain water repellency in clothing; the manufacture of a lightweight unimpregnated cloth which is waterproof and windproof by virtue of its construction alone; a treatment of canvas duck that will make it resistant to fire, water, mildew, and weathering; the development of new fabrics with high tensile strength and superior wearing and wind-resistant qualities;

FOOD

Methods of preserving fresh meats and perishables; dehydration; formulation and packaging of small, compact rations; the coating of cans to eliminate corrosion and decrease visibility from the air; the preparation and distribution of boneless beef; the elevation of the melting point of butter to 150°F;

SHELTER

Development of a jungle hammock, a lightweight poncho, a mountain tent for arctic areas, and a variety of other tents for specific purposes;

INDIVIDUAL AND UNIT EQUIPMENT

The large scale production of skis made of resin-bound veneers; the designing of a lightweight plywood packboard; the lightening of many standard items of equipment; the use of opal glass and a new heating and cooling method to manufacture chinaware that is lighter, thinner, and more resistant to breakage; the development of fully equipped mobile laundries, refrigerators, textile and shoe repair units on trailers; the design of field ranges and small cooking units; and the redesigning of numerous items of individual equipment;

PLASTICS

Hundreds of uses—as a substitute for rubber, in coating fabrics, in place of metal parts on aircraft and vehicles, in clothing, bugles, and numerous other articles.

This listing falls far short of the actual story of research conducted by the Quartermaster Corps. It represents but a small fraction of the projects in which the Research and Development Branch engaged, and it in no way conveys an adequate picture of the "human engineering" by which the Army has brought forth from the interplay of American industry and science the means of making our fighting men masters, and not victims, of the forces of nature.

And what of the future? The very nature of planning, while it is governed by the past and present, is to outline and prepare for the future. How well will we cope with it? To look back and see how quickly and effectively we changed our logistics from a defensive to an offensive campaign after Pearl Harbor is, in part, our answer.

Experience has given us confidence, and necessity has built an organization which, I think, is capable of coping with what time may bring, no matter which way the pendulum of the fortunes of war may swing.

We were faced with many seemingly unsurmountable barriers to progress. A number of materials, formerly considered essential for the production of certain wartime necessities, were denied us by the occupation of the enemy in territories where they were produced. Substitutes and synthetics have been developed to take their place, which, in some instances, are serving better than the original materials. As our demand for subsistence for the men overseas grew, shipping space shrank, a menace to supply. In order to cope with this situation, the development of dehydrated foods now saves more than 90 percent in volume and nearly as much in weight in the case of most vegetables, saving thousands of cubic feet of precious shipping space and many tons in weight. Chemistry has afforded protection against mildew, fungus and fire, greatly reducing the rapid replacement of textiles made necessary by the ravages of weather and climate. New packaging methods not only save weight and space, but insure delivery without loss under the most adverse transportation conditions. Mechanical genius has eliminated many tons and many cubic feet in service equipment, permitting the transportation of repair and salvage machinery by air to inaccessible places, further reducing the necessity of frequent replacements of clothing and textiles. Emergency foods have been developed so that troops are not confined for their subsistence to centralized messes, but are made more mobile and independent, permitting them to operate efficiently as individuals or as small, isolated detachments.

These and many more developments born of necessity have been the result of careful planning and organized intelligence. From these results, we look to the future with confidence.

Research in the Engineering and Technical Service, Signal Corps

THE CHIEF SIGNAL OFFICER'S ORGANIZATION FOR RESEARCH AND DEVELOPMENT

By Major General G. L. Van Deusen

Chief, Engineering and Technical Service, Signal Corps

Major General H. C. Ingles, Chief Signal Officer

THE Chief Signal Officer is responsible for the research, development, procurement, and supply of all signal equipment used by the Army and in addition for the actual operation and maintenance of a sizeable part of such equipment. This article and the articles which follow deal only with the agencies with which the Chief Signal Officer discharges his responsibilities for research and development.

The development of signal equipment for the Army has been performed in laboratories of the Signal Corps working in conjunction with other government research and development agencies and with private industry since 1917; but the technical demands which the present conflict imposed have resulted in an expansion of research and development activities in the Signal Corps so that they now constitute the major continuing activity of the Signal Corps from the point of view of War Department investment in plant and personnel.

It has not been obvious even to many experienced people in scientific and industrial organizations why it has been necessary for the Army and the Navy to conduct research and development of communication equipment in Service establishments when American science and industry provide so many facilities which perform similar functions for civilian requirements. However, the experiences of this war have emphasized as never before the stringent requirements which communication equipment must meet to be suitable for military and naval use. The experiences of the Services have shown that the production in quantity of operatable, maintainable equipment rugged enough to stand the stress of military usage is a large order which calls for maximum effort on the part of both science and industry. Service laboratories have been able successfully to bridge the gap which always exists between basic scientific investigations and practical, producible military models. However, it should not be assumed that the service laboratories are concerned only with production engineering. On the contrary, they are directly concerned with basic research and conduct a considerable amount of such research when for security reasons or because of lack of industrial interest, basic investigations are required in new research fields which have possible military applications.

The present organization through which the Chief Signal Officer administers research and development is the Engineering and Technical Service, one of the four principal operating services of the Signal Corps. Under the direct control of the Chief of the Engineering and Technical Service, are the major research and development laboratories of the Signal Corps, some operated under the Signal Corps Ground Signal Agency and others, until October 15, 1944, operated under the Signal Corps Aircraft Signal Agency. Under the staff supervision of the Engineering and Technical Service are the research and development activities of the Signal Corps Photographic Center and such research and development as is necessary in connection with those fixed communication systems equipments which are operated by the Chief Signal Officer. The Engineering and Technical Service also exercises staff supervision over the Signal Corps Standards Agency which, although it is not directly engaged in research, is contributing a major effort in the establishment of standards for components. Finally, the Engineering and Technical Service coordinates Signal Corps research and development with the New Developments Division of the War Department, other Technical Services of the Army Service Forces, the Navy Department, the Office of Scientific Research and Development, and with agencies of the allied countries which participate in the activities of the Combined Communications Board.

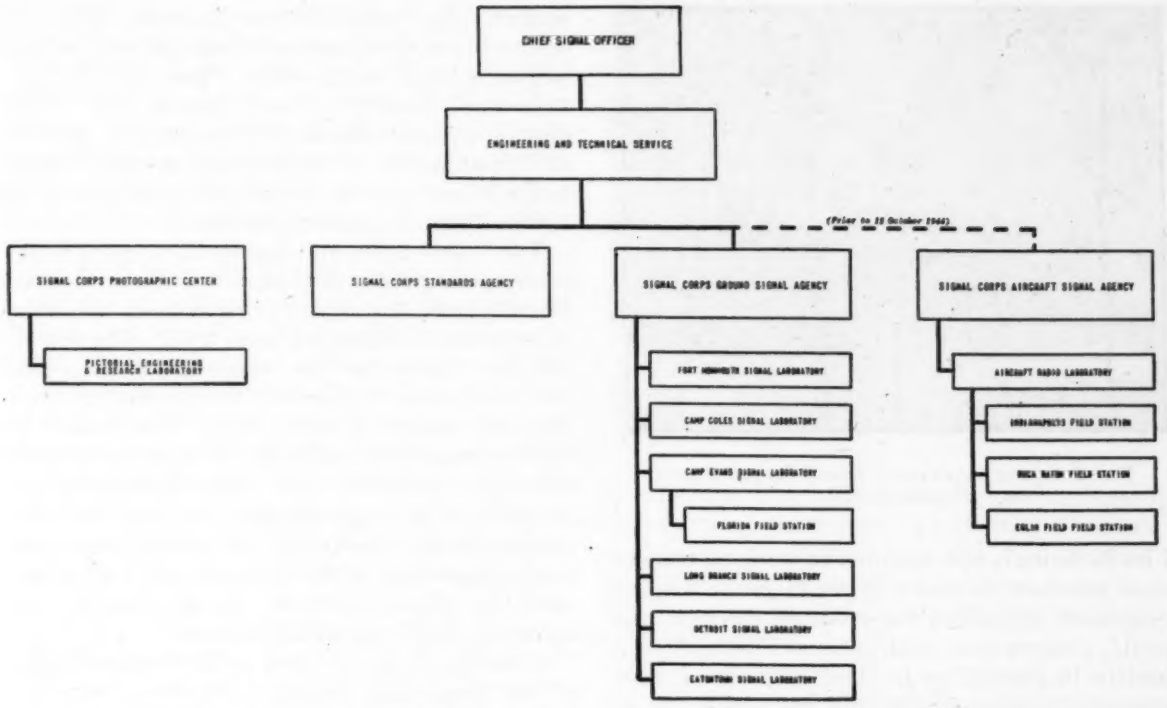

CHIEF SIGNAL OFFICER
ENGINEERING AND TECHNICAL SERVICE
SIGNAL CORPS PHOTOGRAPHIC CENTER
SIGNAL CORPS STANDARDS AGENCY
SIGNAL CORPS GROUND SIGNAL AGENCY
SIGNAL CORPS AIRCRAFT SIGNAL AGENCY

FIG. 1. The Chief Signal Officer's organization for research and development.

LABORATORIES OF THE SIGNAL CORPS GROUND SIGNAL AGENCY

BY COLONEL VICTOR A. CONRAD,
Commanding Officer,
Signal Corps Ground Signal Agency.

ALTHOUGH its present name was not assigned until July 1, 1943, the history of the Signal Corps Ground Signal Agency can be traced back to 1917. At that time, the first Signal Corps laboratory was established at Camp Vail, now Fort Monmouth, New Jersey. Its activities originally were limited principally to the research and development of radio communications systems. This limitation had already been removed when, in 1929, work on wire communication facilities was brought from Washington, D. C. For some time thereafter, the Signal Corps Laboratories remained within the confines of Fort Monmouth, while their activities expanded to take in sound and flash ranging developments for the Field and Coast Artillery, visual and aural signalling devices, sub-aqueous sound detection and meteorological equipment. In 1939, the Laboratory had a personnel authorization of eight officers and about two hundred civilians and an annual budget of about $500,000. In 1944, the personnel authorization of the Signal Corps Ground Signal Agency was three hundred and forty officers and almost eight thousand civilians and a budget of almost forty-three million dollars.

In 1935, a permanent laboratory building was completed at Fort Monmouth but, about two years later, the expanding activity required the establishment of a field station at Fort Hancock, New Jersey. Additional activity established the need for a second field station at Eatontown, in the immediate vicinity of Fort Monmouth, to take care of meteorological and direction finding projects, and this field station was in operation early in 1942. The parent laboratory was operating three field stations, and was re-named the Signal Corps General Development Laboratory early in 1942.

The present organization of the Signal Corps Ground Signal Agency consolidates all laboratory facilities, including activities in addition to those mentioned above, under a single headquarters. Because of further expansion and re-grouping of functions, there are now six laboratories within the Signal Corps Ground Signal Agency. Of these, the Fort Monmouth Signal Laboratory is the oldest, being the direct descendant of the original laboratory at Camp Vail. A large part

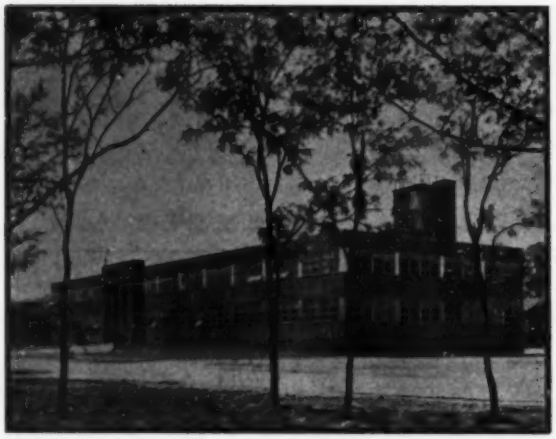


FIG. 2. Squier Laboratory, Signal Corps Ground Signal Agency.

of its facilities is now devoted to work on components common to many types of ground signal equipment. Facilities for research on new materials, components, and processes permit such work to be carried on in close cooperation with industrial, governmental, and university organizations. The large "artificial weather" chambers permit the testing of all kinds and sizes of signal equipment, from small capacitors to the largest Army vehicles carrying the most complex signal equipment, under conditions simulating the extremes of arctic or tropical climates. Mycological research permits evaluation of the effect of various fungi on signal equipment and the formulation of treatments to eliminate or minimize these effects. This fundamental research leads to the development and introduction into production of new components, capable of withstanding the rigors of military service many times better than most standard commercial items. In addition, new materials and manufacturing processes are developed and applied to meet problems of production as well as quality.

As a natural consequence of such activities, the Fort Monmouth Signal Laboratory plays an important role in the standardization of Signal Corps components and materials. The advice of its experts in various fields is utilized to advantage by the Signal Corps Standards Agency and by the other Signal Corps Laboratories. Its test equipment is always available for production approval tests or for special tests required by any of the other laboratories in the Agency.

Of its total personnel, comprising thirty-four officers and about eleven hundred civilians, about one-third are engaged in the activities just described. The remainder are concerned with the research and development of special equipments having general application. These include batteries and flashlights, head phones and microphones, general purpose test equipment, gasoline and diesel power units, and such special vehicles as are required to house and transport the larger items of Signal Corps equipment.

The Camp Coles and Eatontown Signal Laboratories, originally field stations of the General Development Laboratory, have been operating as separate laboratories since 1942. The former handles practically the entire field of ground communication equipment, both radio and wire. Its staff consists of about thirty officers and six hundred and fifty civilians. All types of tactical telephone, teletype, and radio equipment are included in its responsibilities. In fact, the only communication equipment for which Camp Coles is not responsible is the VHF ground equipment used for plane-to-ground communication and light and sound signalling devices.

These latter are included in the responsibilities of the Eatontown Signal Laboratory, together with sound-ranging, meteorological, radio direction finding, and intercept equipment. Approximately equal to Camp Coles in size, the Eatontown Signal Laboratory was staffed as of December 1944 by twenty-five officers and six hundred civilians.

The Camp Evans Signal Laboratory, with a personnel strength of fifty-seven officers and thirteen hundred civilians, is concerned with special electronic equipment. Because of present security requirements, very little can be said about the general activities of this Laboratory.

One activity can be discussed, however, and is sufficiently important to deserve special mention. Vacuum tubes have been the heart of modern electronics equipment, most of which would have been impossible without special new vacuum tubes. It was logical, therefore, to centralize vacuum tube activities in the Camp Evans Signal Laboratory. Facilities are available for research, development, and testing of all the many types of vacuum tubes now used by the U. S. Army. These facilities are available to assist in the solution of vacuum tube problems arising in any of the laboratories of the Signal Corps Ground Signal Agency. They have also been made available as required for solution of vacuum tube problems arising in other services of the Army. These facilities are used in performing the major portion of the tests required

for vacuum tube type approvals by the Signal Corps Standards Agency.

The Camp Evans Signal Laboratory also operates a Field Station at Clermont, Florida. Personnel of this station assist the Army Air Forces Board in testing Signal Corps equipment and in making engineering tests of equipment which requires extensive flights by cooperating aircraft.

The Long Branch Signal Laboratory, with six officers and ninety-eight civilians, performs research, development, and similar services on quartz crystal problems. Here is conducted research on the fundamental properties of quartz and their relation to the requirements of precise frequency control. Facilities are also available for circuit studies and the investigation of production and test methods.

The only laboratory located outside of Monmouth County, New Jersey, is the Detroit Signal Laboratory. In the automotive center of the United States, it is ideally situated to perform its two basic missions. The first of these missions is to make prototype installations of radio equipment in military vehicles; and the second is to develop methods for radio noise suppression of vehicles, power units, and other miscellaneous military equipments. The twelve officers and four hundred and twenty civilians in this laboratory work closely with the Ordnance Department and other procurement services to insure that necessary radio installation and suppression provisions are incorporated in all production vehicles and power units. To insure continuing

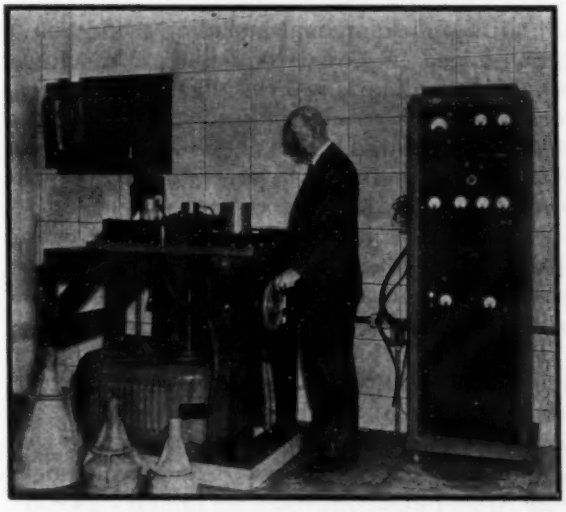


FIG. 3. Vibration equipment for vacuum tube tests, Camp Evans Signal Laboratory.

FIG. 4. Self-contained humidity and temperature control cabinets. Range is −130°F to −70°F with humidity control at higher temperatures. Used for battery and component testing.

effectiveness of suppression systems, a special line of components has been developed. These provide the necessary long life and stability under the conditions of temperature, humidity, vibration, and shock likely to be encountered in a combat vehicle.

Although this article is concerned primarily with research and development on new equipment, it would be misleading if the impression were given that this is the sole activity of the laboratories in the Signal Corps Ground Signal Agency. Quite the reverse is true. A relatively large portion of the laboratories' effort and their first priority is devoted to the preparation of procurement data, including specifications, and drawings and, in some cases, to the fabrication of actual models. Another large contribution to the work load of the laboratories arises from field reports, indicating desirability of changes in existing equipment. Very frequently these changes result from new applications of the equipment, unforeseen by the original designer. In some cases, the acid test of combat use has brought out hidden weaknesses undetected in the most careful service tests. In either case, the engineers in the laboratories must prepare information for changes, to be made either in the field or in future production.

Several vital tasks are performed by personnel of the Signal Corps Ground Signal Agency assigned to the headquarters organization, rather than to the several laboratories. For example, uniformity, accuracy, and completeness of specifications is insured by critical review in the Specifications Clearance Branch before the specifications are issued. Assistance in the solution of production problems is provided by Field Engineering Branch, which maintains one or

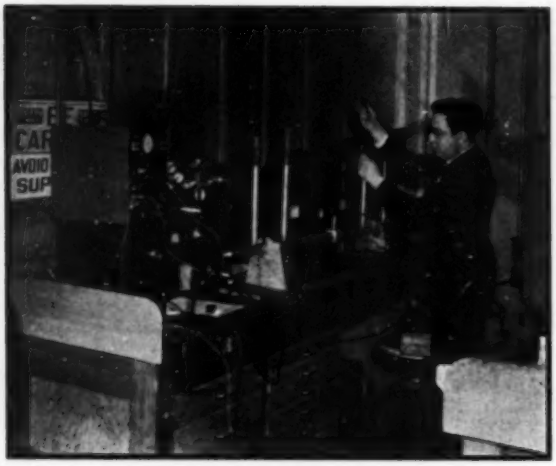


FIG. 5. A developmental model signal generator is checked for compliance with Signal Corps specifications at Camp Coles Signal Laboratory.

more engineers in the plant of each manufacturer having critical production problems. Both these Branches are included in the Quality Control Division of the Agency. The Maintenance Division performs a similar Agency-wide function with respect to the determination of requirements for spare parts; general test equipment; and tools, and assists in the preparation of technical bulletins and manuals concerned with field maintenance problems. Reports from the field on equipment performance are received and analyzed in this Division, and recommendations for improvements are forwarded to the laboratory concerned.

There are now about seventy officers and seven hundred and fifty civilians engaged in these more prosaic tasks, the necessity for which is directly traceable to the ever changing needs of armed conflict. Because of these needs, it has been impossible for the Agency to expand its basic research and development program to keep pace with all aspects of the expansion in war research which has taken place in industry and in the universities and colleges. Instead, the aim has been to assimilate and guide the work of others so as to supplement most effectively the work of the Agency. In this effort, important contributions have been made by members of the civilian technical staff in translating military requirements into tentative technical specifications as a guide for the scientists and engineers of industry and of the Office of Scientific Research and Development.

Another headquarters group, the Engineering Staff, is responsible for insuring coordinated and expeditious action on engineering or technical questions affecting several groups within the Agency.

Many of the prominent members of the prewar technical staff have accepted commissions and are now occupying important technical and administrative positions, both in the Agency and in other Army installations in this country and overseas. In view of the tremendous advances in military electronics applications, it is clear that these and the newer members of the Laboratories' technical staff will have many future opportunities for significant contributions in electronics research and development.

THE SIGNAL CORPS AIRCRAFT RADIO LABORATORY

By Colonel William L. Bayer
Technical Liaison Officer, Engineering and Technical Service, Signal Corps

THE Signal Corps Aircraft Signal Agency, including the Aircraft Radio Laboratory, was transferred to the Army Air Forces in October, 1944. It constituted so important a part of the Chief Signal Officer's research and development activities, and the contribution to the war effort for which the agency has been responsible is so large that it is desirable to include it here in order to present more nearly completely the story of Signal Corps equipment development.

The Signal Corps Aircraft Signal Agency was charged with the research and development of all aircraft signal equipment including ground navigation aids. In order to achieve the closest possible coordination with allied development activities of the Army Air Forces, it was located at Wright Field, Dayton, Ohio. Research and development activities were centered in the Aircraft Radio Laboratory at Wright Field. Flight test activities are conducted there and also at a number of field stations which are located at or near Army Air Force field test establishments.

The Aircraft Radio Laboratory is a comparatively recent addition to Army electronic research and development facilities. Up until 1927, the Signal Corps parent laboratory at Fort Monmouth, New Jersey supervised the development of all Army radio equipment for military aircraft, and only a liaison group was maintained at McCook Field for the main purpose of assisting

in planning installations. However, the growing importance of aircraft communication and navigation was recognized, and in 1927, the Chief Signal Officer established the nucleus at Wright Field of what has now become the Aircraft Radio Laboratory. The best measure of its growth may be seen from the following facts: In 1939, the laboratory had a personnel authorization of ten officers and one hundred civilians and an annual budget of approximately $240,000. In 1944, the authorized strength was about one hundred and sixty officers and eleven hundred civilians, and the annual budget was over twenty-two million dollars. The increase in laboratory space and equipment has been even more impressive since the increased technical and physical requirements of present-day equipment necessitates altitude, tropical and arctic test chambers, as well as a myriad of special types of test and tuning equipment which the more complex types of airborne communications and radar have introduced.

The Aircraft Radio Laboratory plant at Wright Field comprised the main administration building and laboratory and several Laboratory annexes. One of the main facilities on the flying line is an installation hangar large enough to accommodate several flying fortresses. This entire huge hangar was available exclusively for installation, engineering, and testing of aircraft signal equipment. Extensive machine shop facilities to supplement the main engineering shops of the Aircraft Engineering Division were operated by the Radio Laboratory to fabricate development models and installation accessories.

The main laboratory is equipped with several elaborate high altitude test chambers which permit altitude and temperature tests under conditions more severe than any so far encountered in practice. There are also elaborate shake tables for vibration tests as well as the more conventional electric test equipment. However, major emphasis is placed on test flights, and real rather than simulated tests are required before the laboratory seal of approval is placed on an airborne equipment.

The laboratory was initially charged with aircraft communication equipment only, but in 1935 responsibility for radio navigation was added. At the beginning of 1942, the growing importance of detection and identification equipment necessitated a major reorganization of the Laboratory to accommodate the mushroom growth of these important programs. Subsequently, requirements for other new major programs introduced reorganizations so that the Laboratory in 1944 included four major development divisions staffed with an approximate total of one hundred and twenty officers and eight hundred civilian engineering and clerical personnel.

The Aircraft Radio Laboratory has been responsible not only for airborne equipment (i.e., equipment operated in aircraft in flight) but also for the important test equipment required both in the air, on the flying line, and in field and depot repair shops. In addition, the laboratory has been responsible for those equipments used on the ground which are an integral part of air-ground navigation, approach, and landing systems. However, close cooperation with the laboratories of the Signal Corps Ground Signal Agency has been maintained to permit the maximum possible coordination and to avoid unnecessary duplication. The Aircraft Radio Laboratory has depended primarily on the Ground Signal Laboratories for component developments and tests except for those items for which airborne use introduced unique requirements.

Research and development work for airborne signal equipment is a far more strenuous and complicated procedure than most development engineers realize. Equipment for use on the ground can usually be tried, adjusted, retried, and readjusted with only normal brief delays. However, when a piece of airborne equipment is to be tested, many hours of preparation are required to permit a few minutes testing in flight. Despite maximum effort to substitute preliminary ground tests to eliminate obvious deficiencies, the flight test requires elaborate planning and organization in order that the minimum wastage of time in the air will result. The weather must be right; the installation must be almost perfect; the test personnel must be thoroughly trained and briefed; and luck must hold, otherwise many flight test attempts will be completely unsuccessful. Adjustments in the air are difficult at best and in most cases are impossible so that it may take hours to fly, land, adjust, and fly again with an equipment which could be adjusted in a few moments if it only had to be tested on the ground. Flight test pilots, project officers, and test engineers of the Aircraft Radio Laboratory have contributed much with respect to the planning and organization of flight tests of signal equipment which is

reflected only in the efficient accomplishment of their flight missions.

The work of the Aircraft Radio Laboratory has always been mainly directed toward the development of airborne signal equipment and the difficult task of engineering the equipment to fit the airplanes in which it is used. Little, if any, basic research has been performed although military and civilian personnel stationed at the laboratory have made notable contributions in basic radio and electronics particularly in those techniques now utilized in radio compasses, instrument landing systems, and communication frequency antenna systems. While keeping pace with the remarkable expansion in the development of airborne communication equipment, the more spectacular advances have been made in those fields of special airborne electronic equipment which have permitted our aircraft not only to navigate but also to perform combat missions under weather conditions when comparable operation is denied our enemies. Close coordination with British and Canadian scientists, Office of Scientific Research and Development, the major commercial laboratories, and with the Navy has permitted the utilization of new developments in these special classes of signal equipment to be made available for operational use with astounding promptness.

THE SIGNAL CORPS PICTORIAL ENGINEERING AND RESEARCH LABORATORY

By Lt. George Owen
Pictorial Engineering and Research Laboratory, Signal Corps

WHEN it is said that this is the best photographed war in history, the spectacular work of the Signal Corps photographer immediately comes to mind. But behind the remarkable war coverage of still and motion picture cameramen lies a little-noticed story of coordinated research and organization carried out in the Signal Corps Photographic Center at Long Island City by the Pictorial Engineering and Research Laboratory. The continued quality and output of the Army Pictorial Service is the direct result of engineering research toward maintaining and improving the standards and performance of photographic equipment in the field.

The Pictorial Engineering and Research Laboratory, PERL, is concerned with all aspects of still and motion picture photography, both technique and practice. Under this general heading come the diverse and specialized problems of basic research and development, coordination with practice through the experience gained in widely separated war theaters, testing of materials and equipment, origination of procedures for maintenance and repair, and standardization for procurement and manufacture.

The nerve center of PERL around which all its other activities revolve is its testing laboratories. Here highly trained technicians subject all types of photographic equipment to conditions of wear and strain, heat, cold, humidity, vibration, shock, and chemical corrosion surpassing in severity anything to which they will be subjected in normal service. Equipment which in these tests does not meet the exacting requirements of Army use is discarded, or redesigned so that deficiencies are eliminated. Practical recommendations are evolved for tropicalization and winterization; special lubricants are developed for sub-zero and high temperature lubrication, and procedures devised for scientific and efficient maintenance based upon known incidence of wear and exhaustion.

In addition to conducting tests and experiments in the artificially simulated conditions of the laboratories, PERL is constantly engaged in study of reports received daily from officers and enlisted men in the theaters of operation. Returned personnel are interviewed at the Photographic Center, and experiences are analyzed and tabulated. From these sources of information, shortcomings of equipment or practice are recognized, and solutions are devised and made available to the field.

PERL is the source of Pictorial Equipment Maintenance Lists, Lubrication Orders, Procurement Specifications, and general technical photographic information. The tangible results of PERL's activities take form in new and improved equipment, tried and tested material and supplies, and reliable and standardized procedures.

Close liaison is maintained with manufacturers and technical authorities in the photographic industry in order that the progress made by independent research may be quickly applied where possible to Signal Corps photographic equipment. Correlation is maintained with other photographic laboratories of the Armed Forces.

For the first time in history a great conflict has been recorded on film. This has been accomplished successfully under the most adverse and varied conditions. PERL has helped make this

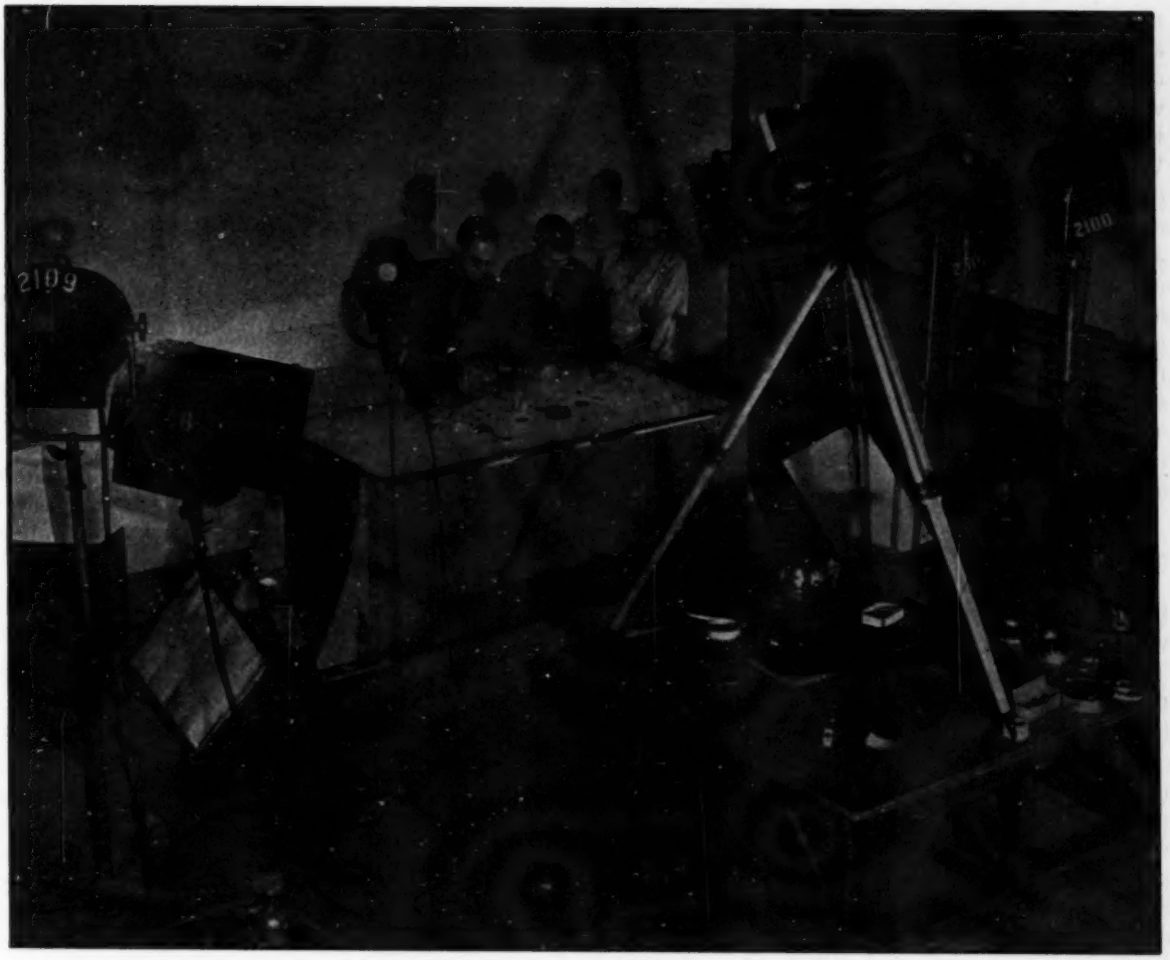


FIG. 6. Camera crew making an exploded view of photographic equipment at Pictorial Engineering and Research Laboratory.

huge task possible by its work of planned research and technical development.

THE SIGNAL CORPS STANDARDS AGENCY

BY COLONEL GORDON C. IRWIN,
Commanding Officer,
Signal Corps Standards Agency.

THE Signal Corps Standards Agency is responsible for the standardization of component parts and materials used in Signal Corps equipment. The standardization program, primarily, accomplishes the following: (a) interchangeability of items, (b) maintenance of quality to meet military requirements, (c) simplification and reduction in number of types, (d) establishment of grades and classes in order that items having least acceptable quality may be used in the less-critical applications. The program has three phases: the *promulgation* of standard specifications; the *qualification testing* of samples under those specifications and the issuance of qualification approval to those items which pass the tests; and the *application* of those specifications to procurements to insure that only approved items are used in Signal Corps equipment wherever practicable. The standardization program is a joint program in which both the Army and the Navy participate.

Standard Specifications

Standard specifications are, for the most part, performance specifications and, with certain exceptions, materials and construction are not specified. Requirements are based, as nearly as is possible, on grades acceptable for use in the

military service and presently available in large quantities. Careful consideration is given to the exacting operating conditions imposed by the war, such as temperature and barometric extremes, humidity, fungus, vibration, and shock. Where compromise is necessary to obtain production, maximum performance possible under existing production facilities is specified. When adequate data to establish certain values are not available, an attempt is made to establish approximate values acceptable to the services and to industry, and the specification is later revised when adequate data are available. In some instances, simplification of number of sizes and styles is accomplished by the specification itself, while in other instances, a preferred list, separate from the specification, achieves this end.

Test and Approvals

Standard specifications prescribe certain tests by means of which the purchaser may determine whether or not requirements have been met. There are two general classes of tests; qualification tests, usually performed at government laboratories which insure that the basic design or composition produces items meeting all of the requirements of the specification; and inspection tests, usually made in the manufacturer's plant, which insure that the production items delivered meet the requirements of the specification. The Signal Corps Standards Agency obtains qualification test samples from the manufacturer and sends those samples to one of several Signal Corps or Navy laboratories for testing under the applicable standard. When the tests are completed, the Standards Agency coordinates the data among the interested service agencies, and if the samples have passed the tests, it issues qualification approval. These are, for the most part, Signal Corps-Bureau of Ships approvals and are accepted by the Canadian services. A very important part of the Standards Agency's work involves assistance to manufacturers in meeting requirements of standard specifications by suggestions for improvements in design, or in quality control.

Application of Standard Specifications

The third phase of the standardization program, the applications phase, is, in many respects, the most important. Standard specifications and qualification approvals thereunder are of little value to the Army unless items approved under standard specifications are used in Signal Corps equipment. In all newly designed equipment, the designers are required to use approved standard items. In reorders of equipment, the use of approval standard items is required through the use, on each contract, of a Standard Parts and Materials specification.

Results of the Program

The program, in its first two years of operation under the Signal Corps Standards Agency, has resulted in the promulgation of thirty-nine (39) standard specifications covering a wide variety of component parts and materials. Over twenty-three hundred qualification approvals had been issued up to December 1, 1944. The success of the program has been due to complete coordination between the Army and the Navy and to the unselfish active cooperation given by the American communications industries.

RESEARCH AND DEVELOPMENT OF SIGNAL EQUIPMENT

By Colonel Robert W. Raynsford,
Assistant Chief, Engineering and Technical Service, Signal Corps.

THE research and development agencies of the Signal Corps have always functioned as part of a team. That team has included the appropriate laboratories of commercial organizations as well as the other corresponding government agencies including the Naval Research Laboratory, the Bureau of Standards, and in this war period, the various laboratories sponsored by the O.S.R.D. which are making such outstanding contributions. The results which this team of scientific, industrial, and military agencies have produced are evidenced in the advanced types of signal equipment which are provided for our Army and Navy.

Any mention of accomplishments which refer to individuals or to a particular laboratory must not be considered to detract from the contributions of other members of the team. It is both impossible and unnecessary to attempt an evaluation of comparative contributions. Nevertheless, as Dr. Vannevar Bush, Office of Scientific Research and Development, so generously stated in his article in the Journal in August, 1943, the Army and the Navy had developed special radio devices as well as many advanced signal equipments long before the emergency and war periods. The following pages touch upon a few of the developments in which Signal Corps

Laboratories had a major part. For security reasons, a great many of the most outstanding scientific developments cannot be mentioned; consequently, this can be only a limited presentation.

One of the most important recent advances made in field radio communications was the introduction of frequency modulation (f-m). To this development for which major credit should be given to Major Edwin H. Armstrong, our land and amphibious armies owe their present excellent radio-phone communications equipment. Frequency modulation was not something which could be taken off the shelf when it was decided that it might be practically applied for military communications. The officers and engineers of the Fort Monmouth Signal Laboratory who realized the potentialities of frequency modulation had first to prove its effectiveness in extensive service tests before the weighty decision could be made to shift the Signal Corps program to this radically different type of equipment. The decision was further complicated by the fact that frequency modulated circuits would be practical for U. S. Army use on available channels only with frequencies controlled by quartz crystal circuits. To make a reasonable number of different frequencies instantly available to each radio set, a large number of crystals would be needed. The problem of developing small inexpensive crystals in sufficient quantities for f-m radio sets appeared to be an almost insurmountable problem which is treated in more detail below. It is sufficient to say here that the timely decision to provide for the Army a complete line of vehicular radio-phone sets using frequency modulation and crystal control was made and the developments completed in time to meet all requirements of our fighting army.

The expansion of the quartz crystal industry in the United States and the development of small inexpensive plentiful crystals for radio frequency control is one of the major war contributions of the Signal Corps. It is well to recall that crystals were rare and expensive in the communication field in 1938. The number of suppliers was limited to six, all producing on a comparatively small scale. In order to provide suitable f-m sets, it was necessary to expand the crystal industry tremendously and improve crystal techniques. The daily crystal production today is roughly equal to the annual production in 1939. Notable progress was made by Signal Corps Laboratories in the dimensioning of crystals for higher frequency use, classification of structural flaws to determine those affecting oscillation and those which did not impair operation, x-ray orientation of faceless quartz, the development of mass production calibration chambers, and the development of mass production methods for grading quartz (during one period 25,000 pounds per week were graded by the Signal Corps Bethlehem Field Laboratory). Courses of instruction were conducted by Signal Corps Laboratories to teach the new crystal industry mass production methods. Production of crystals now is on as large a scale as that of vacuum tubes, with regard to numbers and quality. Military crystal teams were organized, trained and equipped to operate with the field armies to grind blanks to specified frequencies assigned in the theaters and to recover and refinish captured crystals. Special research was sponsored by the Signal Corps Laboratories to determine the causes for aging and deterioration and to develop the present etching method solution.

Military meteorological equipment and developments are often not spectacular enough to attract much attention, yet the dependence of present-day armies on the weather and consequently on weather prediction is so great that it must be given a place not only in local tactical decisions but in strategic planning.

Military use of meteorological equipment is more extensive than is generally realized. Types of equipment which the Signal Corps develops include the following: hand portable observation equipment for Chemical Warfare Service and the Corps of Engineers; semi-portable observation equipment for use by Field and Coast Artillery and Army Air Forces; fixed station meteorological equipment for use at large airdromes and air bases; and automatic weather stations to be planted in inaccessible places for either short or extended periods of operation. The application of data obtained with these equipments is dependent upon continuous development of the theory of forecast for specific end uses, such as planning operations which depend on the presence or absence of fog, rain, or frost, determining whether condensation trails will hamper aircraft operations or planning effective smoke screen operations.

Among the many contributions which Signal Corps officers and engineers have made in meteorological fields is in contributing to the development of the radiosonde. This device,

carried aloft by balloon, transmits by radio periodic readings of temperature, barometric pressure, and humidity. As early as 1930, Colonel William Blair, formerly Director of the Fort Monmouth Signal Laboratory, had pioneered some early work in the development of a radiosonde transmitter to be used in a radio meteorograph to replace the Blair-Rauh meteorograph which was then in current use. In 1937, Colonel Oscar C. Maier, Signal Corps, as a student at the California Institute of Technology, made notable contributions in the development of the Olland type of radiosonde and in the application of ultra-high frequencies for radiosonde use and for wind tracking by radio direction finding. Mr. James W. Goodin of the Fort Monmouth Signal Laboratory developed several radiosonde calibration devices, many of which are incorporated in present standard equipments.

Investigations by the Signal Corps Laboratories of the possibilities of sound ranging pointed to the necessity at an early date for more accurate meteorological data in order that proper meteorological corrections might be introduced in sound ranging tests. This led to a realization of the paucity of available information on the structure of the atmosphere. As a consequence, an extensive program was undertaken under Mr. George D. Lukes of the Eatontown Signal Laboratory to make the necessary studies and tests in order to postulate a practical atmospheric structure which would fit with measured meteorological data and permit ready application to field military problems, both for low altitude and high altitude use. The results of this study have not only permitted the development of practical sound ranging equipment but have led to more useful applications of military meteorological data than were previously possible.

In connection with general investigations by Signal Corps Laboratories of meteorological data applications to military use, work was undertaken on ballistic correction tables for field artillery projectiles. The shortage of ammunition for peace-time firing made it mandatory to fire only under ideal weather conditions. In war time, operations must continue regardless of weather and with a minimum expenditure of ammunition to accomplish the fire mission. The use of a single standard atmospheric table had been continued from the World War I period until 1938. At that time a joint project was set up with the Ordnance Department, U. S. Army, covering meteorological corrections for Ordnance Ballistic Tables. It was soon evident from preliminary investigations that the most important single item in reducing ammunition wastage was accurate meteorological corrections. An extensive program was entered into by the Signal Corps Laboratories to enable full use to be made of meteorological data as it is now provided by military stations. Particularly important was the inclusion of those ballistic corrections based on wind aloft data. This program resulted in the preparation at the Laboratories by Mr. J. C. Brasefield of up-to-date ballistic tables which were used for long range field artillery in the desert campaigns of 1942. It also prompted complete revisions of ballistic tables for all high altitude projectiles including airplane bombs. By the use of a revised regional atmospheric table, decided improvements have been obtained in combat firing. Corrections as large as 20 percent of the range are sometimes necessary.

Many important developments are, like the can opener, so prosaic that their true value is not generally recognized. In this category we find the developments on radio-interference suppression which the Fort Monmouth Signal Laboratories and the Detroit Signal Laboratory have evolved. Without this important contribution, the remarkable performance of Army vehicular radio equipment could not have been achieved. The problem of radio-interference suppression is twofold, including the interference generated by the tires or tracks of the vehicle and that generated by other electrical devices within the vehicle. In the early days of the war, Signal Corps Laboratory teams did the installation and suppression work on mechanized and armored divisions in the staging areas. Signal Corps suppression teams were sent to the theaters to follow up vehicles that had been delivered. At the present time, suppression engineering is coordinated with Ordnance Laboratories when vehicles are designed so that manufacturers deliver vehicles already suppressed.

Among many important contributions which officers and engineers of the Aircraft Radio Laboratory have made are those in the field of radio navigation. Many of these developments are as applicable to commercial aviation purposes as to military purposes, and many of them were in commercial use long before the war. The present type radio compass which is the result of important contributions from many engineers was pioneered by the Aircraft Radio Laboratory. In particular the non-ambiguous right-left indi-

cating feature was contributed by Colonel Herbert G. Messer while serving at the Laboratory. In addition, Signal Corps engineers contributed to the development of automatic features which are included in the present standard radio-compass equipment. Development of the currently used transmission line method for calibrating and testing compasses in a shielded room was developed by an Aircraft Radio Laboratory engineer, the late Mr. John Grieg.

Before the war few people realized the importance of strategic materials. The tire shortage has popularized the subject, but it is doubtful if the advances that have been made in devising substitutes for strategic materials in signal equipment are fully appreciated. The Signal Corps has made large contributions in this program including basic research in developing new alloys, ceramics, and glass, as well as the more plodding tasks involved in testing and trying scores of substitute materials in practical applications.

Of particular interest are the following substitutes which the Signal Corps has developed or sponsored:

(a) Low grade mica for low voltage capacitor applications.
(b) Plastic materials for flashlights and signal lamps and special light projectors.
(c) Polyethylene and polyvinyl insulation for wires.
(d) Magnesium in place of steel or aluminum or wood in radio chassis, antenna masts and antenna mounts.
(e) Development of plasticized ceramics as a substitute for mica in the manufacture of condensers.
(f) Plasticized laminated paper and wood fiber in place of plywood.
(g) Substitution of glass in place of certain ceramics as insulators.
(h) Development of vibration absorbers (shock mounts) of substitutes for rubber and neoprene; the development of substitutes for rubber for meteorological balloons.

Signalling by means of visible light has been a standard means in the U. S. Army for years. A comparison of the heliograph with the most recent signal lamps and optiphones would give a rough idea of the advances that have been made in the use of visible light for signalling systems. The work of a group of engineers at the Fort Monmouth Signal Laboratory, headed by Dr.

FIG. 7. Laying wire by airplane.

S. Herbert Anderson and Dr. Marcel J. E. Golay, was instrumental not only in developing the various light systems now employed, but also for some notable basic developments in the field of heat and light systems as well as in that portion of the radio spectrum in which optical principles could be applied.

The advances made in the field of vacuum tube design in the past few years have been so wide and so rapid as to stagger the imagination. Among the many contributors to this remarkable march of progress there must be numbered some of the engineers of the Camp Evans Signal Laboratory who have pioneered development in many special types of high powered transmitting tubes designed for shock excitation. A chief contributor in this field has been Major H. A. Zahl, whose development of the complete internal oscillating circuit vacuum tube is a major advance in electronics.

One of the chief contributions which the Aircraft Radio Laboratory has made has been in the field of adopting equipment for which basic research was performed elsewhere into rugged dependable equipment which would fit the aircraft in which it was to be used. This sounds simple but the production in what seems like astronomical quantities of aircraft signal equipment represents the culmination of a tedious process of flight tests, altitude (pressure tests), humidity cycling, vibration tests, components tests, and mock-ups, all in an effort to reduce weight and improve dependability.

An ingenious method of developing efficient airplane radio antennas was contributed by the

engineers of the Aircraft Radio Laboratory under the leadership of Lt. Col. George Haller long before the present emergency. This method involved the use of a reduced scale stationary model aircraft and antennas operating at correspondingly increased frequencies. For example, in designing an antenna system to give proper direction patterns for communication use in a radiofrequency band at about 2000 kilocycles on a medium sized transport airplane, the pattern tests would be run with a two-foot model with a miniature antenna operating at a radiofrequency of about fifty megacycles. Results were sufficiently dependable so that they could be used for all but final flight tests and many hours of preliminary flight tests which otherwise would have been necessary were saved.

Telephone equipments, including the best military field telephone, dependable field wire and transmission line cables, field telephone and teletype switchboards, have been developed by commercial facilities working with the Signal Corps Laboratories. However, an outstanding direct Signal Corps contribution is the simple revolutionary device recently developed by Mr. Kenneth J. Way of the Eatontown Signal Laboratory. It consists of a half-dozen thumb size connectors each incorporating a neon signal light which when connected together in a miniature holder constitute a six-line switchboard which can be carried in a soldier's pocket.

Electric batteries, both dry types and storage types, are the fuel for many important communication systems and equipments. Consequently, it is not surprising that the Fort Monmouth Signal Laboratory has made notable contributions in battery developments. Of particular importance in recent years has been the discovery of the Rubin cell invention, a recognition of its potentialities and the necessary scientific development at the Laboratory to justify reconversion of a large portion of the dry battery industry to this new revolutionary type of cell. Captain Grenville Ellis of the Fort Monmouth Signal Laboratory has been largely responsible for this progress and also for noteworthy advances in both the chemical and physical structures of dry battery materials. Discovery by Dr. Virgil F. Payne of practical, available substitutes for shawnigan-black for dry batteries has been another outstanding Laboratory contribution.

The contributions mentioned briefly in the paragraphs above are obviously only a sampling of the total contributions by Signal Corps engineers in recent years. The items mentioned are not necessarily the most important. They have been selected primarily for popular interest and because they present some conception of the diversity of subjects with which the Signal Corps Laboratories have had to deal. Many of the most prominent scientists and engineers who have been associated with the Signal Corps Laboratories as officers or in a Civil Service capacity have been assigned to work on highly secret projects because of their outstanding abilities. Since these projects are classified, it is not possible at this time to discuss contributions which some of these most highly qualified engineers have made. To a score of these and to hundreds of other engineers and to thousands of their assistants, all of whom have labored in anonymity, the Signal Corps, the Army and the Nation owe sincere gratitude for a job well done.

Here and There

The newly formed Midwest Research Institute at Kansas City, Missouri, began full-scale production in February. The Institute's laboratories are being equipped and expanded to cover research activities in chemistry, physics, metallurgy, mineralogy, biology, bacteriology, and chemical, civil, electrical, and mechanical engineering. President is Harold Vagtborg, former director of the Armour Research Foundation, Chicago. The 100 trustees, who represent agriculture, commerce, industry, and educational interests of the Middle West, include Charles F. Kettering, president of General Motors Research Corporation, Dr. Edward R. Weidlein, director of the Mellon Institute of Industrial Research, and Hon. Harry S. Truman, Vice President of the United States.

Dr. Joseph C. Boyce, new Chairman of the Physics Department in the uptown portion of New York University, has been named Secretary of the Physics Section of the American Association for the Advancement of Science for a four-year term. Dr. Boyce was formerly Associate Professor of Physics at Massachusetts Institute of Technology.

With the financial support of the General Electric Company, Union College at Schenectady, New York, will operate a special session, July 9 to August 18, for post-graduate instruction in physics to be attended by forty Fellows, all men who are experienced teachers of science in high schools. They are to be chosen from among candidates presented by school superintendents in 140 cities of over 25,000 population throughout the Middle Atlantic States and New England. Fellowships will cover tuition, maintenance, and travel expense. The Fellow must be under 40 years of age and hold at least a bachelor's degree which represents substantial undergraduate courses in mathematics and physics. Courses given will include Electronics, Modern Physical Theory and Phenomena, and the most novel departure—Modern Application of Physical Measurements, to be given at General Electric Company's research laboratories, largely by General Electric personnel but under academic direction. The College has estimated the residence value of this summer session as a quarter of a year, or eight semester hours. The program has been designed to enlarge each Fellow's grasp of recent developments in physical science, so that "when he returns to his classroom, he will undoubtedly enrich his teaching with new understanding and inspire scientific ambition in the minds of his students."

Science reports the following notes on the recent joint meeting in New York of the American Association of Physics Teachers with the American Physical Society: Dr. R. C. Gibbs, professor of physics at Cornell University, was elected president of the former; the Oersted Medal, awarded annually for notable contributions to the teaching of physics, was presented to Dr. Homer L. Dodge, president of Norwich University, Vermont; Professor I. I. Rabi, of Columbia University, delivered the Richtmyer Memorial Lecture.

On February 21 the Washington Award was conferred by the Western Society of Engineers upon Dr. Arthur H. Compton, Dean, Division of Physical Science, and Chairman, Department of Physics, University of Chicago, "in recognition of devoted, unselfish, and pre-eminent service in advancing human progress through his research and teaching in the physical sciences, increasing man's knowledge of the action of x-rays and cosmic-rays."

Engineers at Station WCAE, Pittsburgh, have achieved what is believed to be an all-time record in maintaining a cathode ray monitoring tube in continuous operation for more than 50,000 hours. The RCA type 904 cathode ray tube, used for monitoring radio programs, was installed in the station's transmitter in August 1939 and is still visibly providing the same clear monitoring picture as it did then. James Schultz, WCAE's chief engineer, reports that the tube shows no perceptible depreciation in sensitivity or definition. The purpose of the cathode ray tube as here used is to assist broadcasting stations to provide higher fidelity transmitting by indicating visually the degree of modulation during program transmission.

New Appointments

Science reports that Dr. Wallace J. Eckert, astronomer and since 1940 director of the Nautical Almanac Office at the U. S. Naval Observatory at Washington, D. C., has been appointed director of the newly organized Department of Pure Science of the International Business Machines Corporation, with offices at the company's headquarters building in New York City.

Dr. D. Gardner Foulke, recently chief chemist for the Garfield Division of Houdaille-Hershey Corporation, has joined the staff of Foster D. Snell, Inc., consulting chemists, as Director of the Analytical Department.

Three new appointments have been announced by National Carbon Company, Inc., a unit of Union Carbide and Carbon Corporation. C. O. Kleinsmith has been elected a Vice President, D. B. Joy has been appointed General Sales Manager for carbon products, and R. P. Bergan as General Sales Manager for the company's consumer and related products.

Bulletin of Mathematical Biophysics

The March, 1945 issue of the *Bulletin of Mathematical Biophysics*, Vol. 7, No. 1, has the following table of contents:

On the Form and Strength of Trees: Part III. The Secondary Branches and Their Relation to the Primary Branches—I. OPATOWSKI.

Muscular Dynamics and Muscular Efficiency: I. The Isometric Length-Tension Diagram of Striated Skeletal Muscle—ALSTON S. HOUSEHOLDER.

Some Nutritional and Excretional Interactions and the Growth of an Organ or Colony—M. F. MORALES AND F. L. KREUTZER.

A Problem in the Mathematical Biophysics of Blood Circulation: I.—N. RASHEVSKY.

A Problem in the Mathematical Biophysics of Blood Circulation: II. Relation between Pressure and Flow of a Viscous Fluid in an Elastic Distensible Tube—N. RASHEVSKY.

A Contribution to the Mathematical Biophysics of Visual Aesthetics—N. RASHEVSKY.

New Booklets

A new 4-page leaflet describing *X-Ray Diffraction—An Industrial Tool* has been announced by North American Philips Company, Inc., 100 East 42 Street, New York 17, New York. It explains the technique employed in *Norelco* film-type x-ray equipment for identification of materials. Simple sketches representing typical diffraction films are exhibited in order to show how comparisons are made. The following industrial applications for x-ray diffraction are listed: (1) Establishment of identities in ceramic clays, (2) Checking ingredients of dairy products, (3) Quality tests on soapstone before firing, (4) Determination of

covering quality of paint pigments, (5) Differentiation of natural and artificial pearls, (6) Identification of aluminum oxide modifications, (7) Differentiation of inorganic fibers, (8) Metallic deposition in formation of metallic carbides, and (9) Determination of character of metallic films.

Allied News, published by Allied Radio Corporation, in its December issue features a discussion of color television. Free literature on electrical equipment is offered by the company to readers of this leaflet. Address the company at 833 West Jackson Boulevard, Chicago 7, Illinois. *Allied News* for January features an article on the use of the Radiosonde in the science of weather forecasting, and discusses other electronic and radio devices. Available from Allied Radio Corporation, 833 West Jackson Boulevard, Chicago 7, Illinois.

The following pamphlets of new mathematical tables are obtainable from the National Bureau of Standards, Washington 25, D. C.: *A New Formula for Inverse Interpolation*, H. E. Salzer. (Reprinted from Bulletin of the American Mathematical Society, August, 1944). 4 pages, with cover, 25 cents. *Coefficients for Interpolation within a Square Grid in the Complex Plane*, Arnold N. Lowan and Herbert E. Salzer. (Reprinted from Journal of Mathematics and Physics, August, 1944). 11 pages, with cover, 25 cents. *Table of Coefficients for Differences in Terms of the Derivatives*, H. E. Salzer. (Reprinted from Journal of Mathematics and Physics, November, 1944). 4 pages, with cover, 25 cents.

A new permanent magnet manual of interest to everybody concerned with the application of the permanent magnet to various industries has been prepared by The Arnold Engineering Company, 147 East Ontario Street, Chicago 11, Illinois. Contents include such subjects as magnet materials, resistance comparisons, physical and magnetic properties, demagnetization and energy curves, fabrication, design, and testing. Charts and tables are included to illustrate and explain various aspects of the discussion. The new manual is available on request to The Arnold Engineering Company.

Walker-Jimieson, Inc., wholesale distributors of radio and electronic supplies, have published an "availability list" as of December, 1944. It is a detailed catalog of electrical equipment for industry and research containing 40 pages and is available from the company at 311 South Western Avenue, Chicago 12, Illinois.

Interchemical Review, Volume 3, Number 4, of 30 pages, includes articles entitled "The Evolution of Mills for Grinding," "The Rheological Concepts of Viscosity and Yield Value," and "The Queen City Printing Ink Company." It is published quarterly by the Research Laboratories of Interchemical Corporation, 432 West 45 Street, New York 19, New York. Address all correspondence to the editor.

Industrial Bulletin for January 1945, issued by Arthur D. Little, Inc., chemists and engineers at Cambridge, Massachusetts, contains several industrial forecasts in articles on rubber progress, postwar highway construction, plastics, and the improvement of textiles through the application of chemistry.

The *Ohmite News* for January 1945 featured a description of the new electronic system for the bulk reduction of penicillin solution, developed by RCA engineers, which made possible a tremendous and life-saving increase in the production of the famed drug. Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago 44, Illinois.

The National Inventors Council, C. F. Kettering, Chairman, has issued a pamphlet listing 25 inventive problems for which the Navy Department is seeking solutions. The pamphlet may be obtained by writing to the Council at the Department of Commerce, Washington 25, D. C.

The Graham Dial, published monthly by Graham Transmissions, Inc., Milwaukee 12, Wisconsin, is "a convenient monthly abstract of interesting articles from the technical press together with timely news about variable speed drives, particularly the Graham."

Precision Scientific Company, designers and builders of modern laboratory equipment, announces a new line of safety heaters for heating complex glassware set-ups involving distillation columns, cumbersome flasks, delicate reflux condensers, and other costly glassware. Bulletin HP-1650, a booklet describing them, may be obtained by addressing the company at 1750 North Springfield Avenue, Chicago 47, Illinois.

A list of the 48 mathematical tables which have thus far been prepared by the Mathematical Tables Project and made available to the public is given in Letter Circular LC-777, just issued by the National Bureau of Standards, Information Section, Washington 25, D. C. Thirty-one of these tables may be purchased from the Bureau, two from the Government Printing Office, four from the Columbia University Press, and nearly all of the remainder can be consulted in the several mathematical journals referred to.

New Books

Natural and Synthetic High Polymers

By Kurt H. Meyer, translated by L. E. R. Picken. Pp. 690+xviii, Figs. 180, 15×23½ cm. Interscience Publishers, Inc., New York, 1942.

Bearing the subtitle "a textbook and reference book for chemists and biologists," this work is the English translation of the second volume of Meyer and Mark's German book *Der Aufbau der hochpolymeren organischen Naturstoffe*, 1939–40 edition. The translation of the first part of this comprehensive publication appeared in 1940 under the title *Physical Chemistry of High Polymeric Systems*,[1] by H. Mark. Both volumes are in the Interscience series on high polymers, and in consequence of their genesis, are complementary.

The present volume was written to provide an up-to-date survey of the knowledge of high polymers, with emphasis on the chemical nature and the structure of the substances themselves. This plan, however, has been interpreted broadly, so that one finds in the book much material on the x-ray and other physical techniques for studying high polymers in solution and in the solid state. Abundant use is made of the x-ray diffraction method in particular. In general, however, development of the analytical theory of the physico-chemical techniques is left to Mark's companion volume. Because of the close attention given to the chemistry of high polymers, with indications of the applicable physical methods of investigation, the present volume should serve admirably as a reference book for the physicist, whether he is specializing on the development of a particular technique for application to high polymers, or is concerned with the physical properties of materials in general.

[1] Reviewed in J. App. Phys. **12**, 190 (1941).

The good organization of the book facilitates its use for reference. Following an introductory chapter on the study of high polymers, the contents are divided along lines of chemical constitution: inorganic high polymers; hydrocarbons; ethers, esters, etc.; cellulose and related substances; starch; and proteins. The book is brought to a close with chapters on the properties of high polymers in solution; films, foils, and membranes; and animal and plant tissues.

The author takes a comprehensive view of the field of high polymers, as is indicated by his inclusion of clays, diamond, and glass, on the one hand, and the electric organ in living tissue on the other. A scholarly approach is exemplified by his advocacy of caution in the use of Staudinger's well-known relationship between molecular weight and viscosity.

W. James Lyons
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Luminescence of Liquids and Solids and Its Practical Application

By Peter Pringsheim and Marcel Vogel. Pp. 201 and x; Figs. 72; 16×23½ cm. Interscience Publishers, Inc., New York, 1943. Price, $4.00.

The first book wholly devoted to fluorescence was written by Pringsheim more than 20 years ago. A vast amount of new theoretical and applied knowledge has been accumulated since, and this new book by the same senior author and M. Vogel attempts to cover most of the practical applications of luminescence phenomena. It is the first good book in English on the subject, although many who know the author's distinguished background will feel disappointed with the short and elementary treatment presented. However, the authors apparently have endeavored merely to write an introduction into the field and in this they have, on the whole, succeeded well.

The book is divided into two sections, the first half dealing with the theoretical and phenomenological background, while the second equally long part is devoted to the main theme of the work. This makes for a somewhat unbalanced presentation inasmuch as the book was written with the aim to "treat luminescence specifically for its possibilities in practical applications." Deliberately, a critical attitude has been exercised throughout, designed as a damper for over-enthusiasm with regard to fluorescence possibilities, and as a suitable means of presenting controversial material.

After an interesting historical introduction, fundamental concepts of light, luminescence, and related topics are discussed briefly. In spite of its brevity the treatment is good within the scope of the book. Interesting is the negative-definition of luminescence as radiation which does not obey Kirchhoff's law. The newer facts and theories regarding the fluorescence of solids, however, are barely mentioned, not even by literature references,—a policy which this reviewer can not find justifiable. The correlation between luminescent phenomena and other fundamental characteristics of solid matter is far advanced beyond the stage of speculation and would seem a necessary chapter in any modern introductory treatise on applied fluorescence of liquids and solids. On the other hand, much of the matter discussed in the following chapter on experimental technique seems to be beyond the scope of the book. Sources of exciting radiation, photometry, phosphoroscopes, and other subjects are given a comparatively broad treatment. Nevertheless, one is surprised to find no mention of such widely used and simple devices as the germicidal types of lamps as sources for short UV radiation, even with all due respect for the policy that it is "impossible to enumerate every mercury lamp, etc. manufactured in the USA."

In the chapter on luminescent materials the organics, minerals, and glasses are treated quite concisely, while the sections dealing with inorganic phosphors are inadequate from a present day standpoint. The difficulties involved in obtaining pertinent up-to-date information are appreciated. However, considerably more material of importance could have been brought out from published data in scientific literature and patent disclosures, or from other sources of information. On the other hand, this reviewer finds a welcome omission of the multitude of pet formulas and recipes for the production of sulfide phosphors, particularly of the earth alkali group, which one finds so often. This chapter will require considerable revision in a future edition.

In the second part of the book, the chapter on fluorescence analysis in its various aspects is by far the best among the different topics discussed in the book. A great deal of material is presented in condensed form and with good critical judgment, giving a sound survey of the present situation and of possibilities for the future.

The sixth chapter on luminescence as a light source is again found wanting. The discussion of the luminescence aspects of cathode ray tubes, fluorescent lamps, etc. is fairly good but inadequate from a more than just introductory standpoint. The problems involved are more complex and diversified, and many results achieved are a good deal better, than the authors allow. An erroneous statement is made on p. 162 regarding the efficiency of λ2537 production in F lamps which is reported as only about 60 percent of the Hg radiation instead of about 85 percent; this is based on an apparent misinterpretation of the original German paper quoted. There are several more incorrect statements which shall not be discussed here. A short list of the better known organic and inorganic fluorescent materials concludes the book.

The book is written in an entertaining and stimulating style and has numerous good illustrations. Print, paper, and exterior makeup are excellent. Figure 10 should be redrawn—the three dotted curves representing the product of energy and visibility can not cross over the respective energy curves if plotted on the same scale. In addition to the literature references the book has a great many footnotes which do not facilitate easy reading; most subjects treated here would have fitted well into the immediate context. Real criticism is in order regarding the superficial proofreading of the book. Literature references, authors' names, chemical formulas, etc. are all too frequently given incorrectly. This includes many statements in the text so obviously wrong that proofreading should have caught them at a glimpse. Reference is made to such lapses as 10^{-5} wattsec. instead of 10^{-19} (p. 19); watts per seconds instead of wattseconds (p. 22) and many more. The quantum yield is, of course, the reciprocal of that given on p. 23 (occasionally authors prefer to determine the number of quanta of exciting radiation necessary to produce one quantum of fluorescent radiation in order to obtain values of quantum efficiencies; apparently these definitions were mixed up). Many more mistakes are too numerous and trivial to mention.

On the whole, it is felt that the book would have been much more valuable if at least its second part would have been more extended, covering not more territory but furrowing somewhat deeper. Thus the book will not quite satisfy those who are closely associated with work on fluorescence. In spite of its shortcomings, however, it will serve as a good introduction for the increasing number of newcomers to the field.

H. C. Froelich
General Electric Company

Time Bases

By O. S. Puckle. Pp. 204+xii, Figs. 124. John Wiley & Sons, Inc., 1943. Price $2.75.

A time base is a device that generates a voltage rising linearly with time. Such devices are widely used with cathode-ray oscilloscopes to produce deflections proportional to time for the delineation of wave forms, both periodic and transient. They are also used to produce television rasters. Other applications include the measurement of short time intervals and the generation of electrical waves of saw-tooth form. In this book are treated the various electronic circuits that can be used to produce time bases.

It has been the author's aim to provide a presentation of principles, rather than a compendium of inventions or commercial circuits. In each case the historical aspects are considered, the operation of the circuit is described in detail, and the effects of changes in the various circuit constants are discussed. Warning is given of possible difficulties, and practical limitations are pointed out. A good starting point is thus provided the reader in working out the constants best suited to his peculiar problem.

A systematic classification of the various types of time bases is set up, and their adaptability to various problems is evaluated. In addition, various related devices, such as trigger circuits, blocking oscillator circuits, push-pull deflection circuits, and polar coordinate time bases are described. Attention is also given to problems of linearization and synchronization. Appendices are devoted to further related subjects, including the cathode-ray tube itself, gas-discharge tube behavior, differentiating and integrating circuits, and square-wave generators; an adequate index is provided.

Throughout the book the presentation is both clear and interesting, being addressed to the reader with a general knowledge of basic electronic circuits. While British vacuum tubes are usually specified, most of the circuits are described generally, with reference to types of tube characteristics, and therefore no serious detriment results. It is apparent that the author has done a great service for research and development people by bringing together in one book all of the pertinent art in this important field.

Hugo Schuck
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Explosions: Their Anatomy and Destructiveness

By Clark Shove Robinson. Pp. 88+vii, Figs. 27. McGraw-Hill Book Company, Inc., New York, 1944. Price $1.50.

This book attempts to provide, in as non-technical language as possible, a summary of those facts concerning explosives and explosions which are most likely to help persons working with explosives to avoid accidents or to minimize damage from them. The choice of material and the conciseness of the style reflect the aim of the author to produce a book which would be widely read by such people, and be of immediate practical value to them. To make the book as widely readable as possible, physics and mathematics are used only at the most elementary level, and derivatives and integrals are introduced with apologies. A number of the graphs are presented in colors to make them easier to interpret.

It should be clear from the foregoing that it would be inconsistent with the author's purpose to attempt a thorough treatment of the basic physics of explosions and explosion damage. Moreover, it is to be expected that many of the substantial and interesting developments in this field must be withheld from the general public in the interests of military security. But because of the lack of published books in this field even a short and elementary book may be of interest to many technical readers as a possible source of a few crumbs of substantial knowledge. To such readers this book will be disappointing. The author shuns precise statements of physical laws—even the similarity law for shock waves from charges of different sizes is not clearly stated, and is applied with doubt and suspicion. Moreover, the first two-thirds of the book seem to have been rather carelessly and hastily written, as evidenced for example by a confusion between absolute and centigrade temperatures on page 6. Fortunately the last few chapters, which give data on the destructiveness of explosions and the author's conclusions regarding safety measures, seem to have received more careful treatment.

For those who handle explosives the book fills a real need. The scientist will find it interesting and stimulating, despite its shortcomings.

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Sampling Inspection Tables

By Harold F. Dodge and Harry G. Romig. Pp. 106. John Wiley & Sons, Inc., New York. Price $1.50.

This book is a collection of tables, curves, and formulae for use in constructing an acceptance inspection plan which will involve a minimum of inspection for a prescribed degree of protection.

The important method which has come in recent years to be called "quality control" consists primarily in the examination of the product as manufactured by use of techniques such as the Shewhart Control Chart and the removal of the causes of defective product, and second in "acceptance inspection" of lots (or *quality determination*) by the manufacturer or purchaser. The present book is concerned with this second part of the subject.

The book is a reprint of three articles which appeared in 1929, 1941, and 1942 in the Bell System Technical Journal. This origin, together with the background of successful use by the Bell System of the tables contained in the book, affords ample evidence of their practicality.

Two classes of tables are offered from the viewpoint of assurance: those tables which provide, with a risk of one chance in ten, that accepted lots will not contain a proportion of defects in excess of some chosen value, such as two percent; those which provide, regardless of the incoming quality, that the "expected" proportion defective articles in accepted lots will not exceed some chosen value, such as one percent.

Two classes of tables are offered from the viewpoint of procedure: those tables which require a single sample from each lot, and those which require a first sample from the lot, and, depending upon the results of the first sample, possibly a second sample.

In the matter of scope, these tables apply only to inspection by attributes; i.e., the classification of articles simply as "good" or "not good," without regard to degree. Manifestly they are not adapted for use where testing or inspection is of a destructive nature, since the system requires that the entire lot be inspected when the sample is more defective than a tabulated value.

Statistical theory has provided some additional techniques for acceptance inspection, since the papers reprinted in this book were written. Among these are sequential plans and operating characteristics, and also the minimization of combinations of cost and risk other than simply the cost of inspection. These things should not be held against this valuable piece of pioneering work; they are mentioned only by way of warning against blind following of any stereotyped procedure in this subject. "Sampling Inspection Tables" comes as close to being a safe guide for engineers not familiar with statistical theory as any book available.

In time, such tables as these may become widely used in writing contracts between manufacturers and large

scale purchasers, to provide each with a criterion of quality which is both economical and objective. But it may be found in the end that the greatest benefit accruing from these tables will be neither this nor their primary purpose of direct protection for the purchaser, but instead the *reaction of the sampling plan on the manufacturing process.* In the words of the authors, "Thus, while the inspection procedures have as their immediate purpose the provision of a curative technique whereby product already made is cleared of abnormal proportions of defects, they are found by experience to enforce the adoption of a preventive technique—one that exerts economic pressure to track down and remove causes of abnormal quality variations, thus enforcing control of quality in the process and assuring better health in the product of tomorrow."

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A Treatise on the Theory of Bessel Functions

BY G. N. WATSON. Pp. 804+vi, Figs. 33, 19×26 cm. The Macmillan Company, New York, 1944. Price $15.00.

The appearance of this venerable classic in the column of new books will elicit some surprise among readers who have had any contact with Bessel functions in their work and have thus come to recognize this volume as the authority on the subject for the past twenty years. The occasion of its present appearance is, of course, the publication of a second edition of the treatise, undoubtedly prompted by an insistent public demand after the first edition had gone out of print.

The second edition may disappoint specialists in the subject of Bessel functions, in that all of the developments in the subject since 1922 have not been included, but to most mathematicians and probably all physicists, the omission of some recent work will detract little from the value of the book. The revision has largely been confined to the correction of minor errors and misprints, and to the emendation of certain statements which, while correct in 1922, would no longer be so in the light of recent developments.

Since there is little more, one can say about the second edition as contrasted with the first, it may be well to take this opportunity to describe the contents of the book briefly for those (undoubtedly few) readers who have not had occasion to examine the first edition. The principal purposes of the book are two in number: first, to provide a comprehensive development of the properties of Bessel functions, and second to provide an exemplary development of the applications of the fundamental methods and processes of modern mathematical analysis. Consequently, the volume is of double value to the mathematician and theoretical physicist, in that it provides not only an invaluable reference on the subject of Bessel functions, but also illustrations of the powerful techniques of the theory of functions of a complex variable which may be applied to numerous other functions which arise in various physical and mathematical problems.

Included in the book are chapters on the history of Bessel functions, Bessel coefficients, Bessel and associated functions, Bessel's and related differential equations, asymptotic expansions for functions of large argument and functions of large order, addition theorems, integrals involving Bessel functions, and various types of series involving Bessel functions (Neumann, Kapetyn, Fourier-Bessel, Dini, and Schlömilch series), as well as extensive tables of Bessel functions, and an exceptionally complete bibliography. Among the analytical methods employed in the book, certain ones, such as the methods of obtaining asymptotic expansions, and methods of evaluating contour integrals (including the method of steepest descent) are invaluable to the theoretical physicist because of their wide application in physical problems.

Bessel functions appear consistently in theoretical problems in all branches of physics, but, in particular, familiarity with their properties is absolutely essential to workers in such diverse fields as mechanics, electromagnetic theory, acoustics, elasticity, heat conduction, hydrodynamics, and quantum mechanics, to mention but a few. While few will desire or find it necessary to read this book from cover to cover, the reviewer feels safe in predicting that this book as a reference volume, will not stand unused on the shelf of any conscientious worker in theoretical physics or applied mathematics.

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Ultra High Frequency Radio Engineering

BY W. L. EMERY. Pp. 295+x. The Macmillan Company, New York, 1944. Price $3.25.

This book is intended primarily as a text for use in colleges giving courses in Ultra-High Frequency Techniques under E.S.M.W.T. and follows very closely the outline agreed on by the delegates to the Electronic Conferences held at Massachusetts Institute of Technology in 1941 and 1942. As such, the text is probably the most satisfactory available for use in such courses, giving a logical and concise presentation of the subject matter and including only that material which is essential. There is thus imposed a lack of freedom as to sequence and content which makes the text serve as an introduction to the field rather than an authoritative source of material of general importance. As a result the treatment of some of the material may seem inadequate, although the author has sought to supply omitted material by the inclusion of rather complete references at the end of each chapter. The problems and experiments included at the end of each chapter are also in the form of suggestions rather than complete exposition.

The book will be found to be a very workable outline for the teaching of undergraduate courses in ultra-high frequency engineering, but may require supplementary exposition. The text is remarkably free from errors, and the terminology and symbols are consistent throughout. Illustrations are clearly and carefully drawn, while the exposition is exceptionally well done except for the brevity mentioned. Subjects treated are: voltage regulated power supplies, electron switching, cathode ray tubes and circuits, amplifiers including wide range types and compensation methods, square wave testing, ultra-high frequency circuit elements and transmission lines, oscillators and U.H.F. generators, modulation, receivers and transmitters, radiation and propagation, wave guides, and electromagnetic horns.

JOHN R. MARTIN
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Letter to the Editor

WESLEY E. BRITTIN
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AND
MAYNARD G. ARSOVE
Brown University, Providence, Rhode Island
January 29, 1945

THE article by E. T. Benedikt[1] and letters by I. F. Morrison[2] and Leon Beskin[3] have shown quite clearly how rigid rotations can be represented by vector operators, thus obviating the need for quaternions. However, corresponding results have been obtained and used in the theory of groups and group representations.[4] We shall present the following development, essentially that of Murnaghan,[5] and show the connection between these results and those obtained by the previous vector methods.

Let x be a vector, $x=\begin{pmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_n \end{pmatrix}$, in a given n-dimensional vector space V_n, and let S be an $(n\times n)$ matrix which operates on x to yield a new vector y of V_n,

$$y=Sx.$$

If we require that y be orthogonal to x for every x of V_n, then

$$x^*y=x^*Sx=0,$$

an asterisk being used to signify the transpose of a matrix. The last equation holds if and only if $S^*=-S$, so S must be taken to be skew-symmetric. Now let us look for a vector ξ which is orthogonal to the vector y generated by a fixed S from any x in V_n,

$$\xi^*y=\xi^*Sx=0.$$

This implies

$$S\xi=0.$$

The set of ξ's so obtained spans an $n-r$ dimensional subspace of V_n, where r is the rank of S.

It is a peculiarity of three-dimensional space that, for S not identically zero, $n-r=1$, and so $S\xi=0$ always has a solution which is unique to within a scalar multiplier. In fact, putting

$$S=\begin{pmatrix} 0 & \alpha & \beta \\ -\alpha & 0 & \gamma \\ -\beta & -\gamma & 0 \end{pmatrix} \quad \text{and} \quad \xi=\begin{pmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{pmatrix},$$

there results

$$\begin{pmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{pmatrix}=\lambda\begin{pmatrix} \gamma \\ -\beta \\ \alpha \end{pmatrix}.$$

Hence, for V_3 we have the theorem: given a non-zero vector ξ, we can determine a non-zero matrix operator S such that for any vector x, $y=Sx$ is a vector orthogonal to both x and ξ. S is the matrix

$$S=\frac{1}{\lambda}\begin{pmatrix} 0 & \xi_3 & -\xi_2 \\ -\xi_3 & 0 & \xi_1 \\ \xi_2 & -\xi_1 & 0 \end{pmatrix}$$

with characteristic roots 0, $i\vartheta$, $-i\vartheta$, where

$$\vartheta^2=\xi^*\xi/\lambda^2.$$

Since the exponential series converges for all square matrices,[6] we can define a (3×3) matrix Θ as

$$\Theta=e^S=E+S+(1/2!)S^2+(1/3!)S^3+\cdots,$$

E designating the three-dimensional unit matrix. Then

$$\Theta^*=\exp(S^*)=e^{-S}=\Theta^{-1},$$

shows that Θ is orthogonal. That the vector ξ is invariant under the orthogonal transformation Θ follows from the definition of Θ, for

$$\Theta\xi=(E+S+(1/2!)S^2+\cdots)\xi=\xi.$$

Let us rotate the reference frame in such a manner that ξ lies along the first coordinate axis. That is,

$$\xi=Pu,$$

where P is an orthogonal matrix of the rotation group, and $u=\begin{pmatrix} \lambda\vartheta \\ 0 \\ 0 \end{pmatrix}$. Setting $\Theta'=P^*\Theta P$, the equation $\Theta\xi=\xi$ becomes $\Theta'u=u$. From this and the fact that Θ' has the same characteristic roots as Θ, i.e., 1, $e^{i\vartheta}$, $e^{-i\vartheta}$, it is evident that

$$\Theta'=\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\vartheta & \sin\vartheta \\ 0 & -\sin\vartheta & \cos\vartheta \end{pmatrix}.$$

Therefore Θ represents a rigid rotation of magnitude ϑ about an axis along the vector ξ.

We shall call the (3×3) matrix X, obtained by taking λ to be numerically equal to unity, the bivector associated with the vector ξ of V_3. There is thus a one-one correspondence between vectors and bivectors,

$$\xi=\begin{pmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{pmatrix}\leftrightarrow X=\begin{pmatrix} 0 & \xi_3 & -\xi_2 \\ -\xi_3 & 0 & \xi_1 \\ \xi_2 & -\xi_1 & 0 \end{pmatrix}.$$

The above results can be stated in the form of a theorem: for a given vector ξ in V_3, the matrix $\Theta=e^X$, X being the bivector associated with ξ, represents a rotation of angle ϑ abour an axis along ξ, where ϑ is numerically equal to the magnitude of ξ.

Every matrix satisfies its own characteristic equation, so

$$S^3+\vartheta^2S=0,$$

and under this recurrence relationship the exponential function e^S becomes the quadratic matrix polynomial[7]

$$e^S=aE+bS+cS^2.$$

To determine a, b, and c, put S, and consequently e^S into diagonal form

$$S\sim\begin{pmatrix} 0 & & \\ & i\vartheta & \\ & & -i\vartheta \end{pmatrix}, \quad e^S\sim\begin{pmatrix} 1 & & \\ & e^{i\vartheta} & \\ & & e^{-i\vartheta} \end{pmatrix},$$

whence $a=1$, $b=\sin\vartheta/\vartheta$, $c=(1-\cos\vartheta)/\vartheta^2$, and

$$\Theta=e^S=E+\sin\vartheta S/\vartheta+(1-\cos\vartheta)S^2/\vartheta^2.$$

The connection between the matrix and vector methods is simply shown in the following fashion: Represent by r the position vector before rotation, and by r' the position vector after rotation. Then

$$r'=e^Sr=r+\sin\vartheta Sr/\vartheta+(1-\cos\vartheta)S^2r/\vartheta^2.$$

The vector $\mathbf{h}=(1/\vartheta)\xi$ is a unit vector whose components are the direction cosines of the axis of rotation. Sr/ϑ represents the vector product $\mathbf{h}\times\mathbf{r}$, and the matrix operator S may thus be depicted as the vector operator $\vartheta\mathbf{h}X$. In the notation of Benedikt the results from group theory yield

$$\mathbf{r}'=e^{\vartheta\mathbf{h}X}\mathbf{r}=\mathbf{r}+\sin\vartheta\mathbf{h}\times\mathbf{r}+(1-\cos\vartheta)\mathbf{h}\times(\mathbf{h}\times\mathbf{r}).$$

[1] E. T. Benedikt, J. App. Phys. **15**, 613 (1944).
[2] I. F. Morrison, J. App. Phys. **15**, 802 (1944).
[3] Leon Beskin, J. App. Phys. **15**, 802 (1944).
[4] F. D. Murnaghan, *The Theory of Group Representations* (Johns Hopkins Press, Baltimore, 1938).
[5] F. D. Murnaghan, *The Theory of Group Representations* (Johns Hopkins Press, Baltimore, 1938); and an unpublished lecture, "A Modern Presentation of Quaternions," Brown University Mathematics Colloquia (Fall 1943).
[6] Reference 4, p. 55.
[7] Reference 4, p. 237.

Proceedings of the Electron Microscope Society of America

THE second meeting of the Electron Microscope Society of America, was held at the La Salle Hotel in Chicago, Illinois on November 16, 17, and 18.

Titles and abstracts of the papers presented are given in the following pages.

1. Two New RCA Electron Microscopes (Invited Paper). PERRY C. SMITH AND ROBERT G. PICARD, *Radio Corporation of America, Camden, New Jersey.*

2. A Discussion of the Illumination in the Electron Microscope (Invited Paper). J. HILLIER AND R. F. BAKER, *Radio Corporation of America, Princeton, New Jersey.*

3. Magnification Calibration of Electron Microscopes. L. A. MATHESON AND R. D. HEIDENREICH, *The Dow Chemical Company, Midland, Michigan* (Time 20 min.). —Polystyrene-silica replicas have been obtained from diffraction gratings ruled on speculum. Electron microscope determinations of the spacing made on groups of lines over different regions of a single screen and from different screens show deviations of less than 1 percent. The average spacing in the silica replica can be determined by diffraction methods if it is partially aluminized. For a silica replica (from a polystyrene molding) mounted in a specimen holder ready for use in the microscope, a 2 percent increase in spacing is observed over the original grating. The agreement among screens is better than ½ percent. The silica films are not subject to distortion while in the electron microscope and appear to make accurate and permanent standards for magnification calibration. The original gratings are excellent subjects for study and comparison of replica techniques.

4. Chemical Electron Microscopy. R. T. PHELPS, A. L. LANGER, AND EARL A. GULBRANSEN, *Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania* (Time 15 min.). —The several variables which are important in the production of reproducible crystal forms for electron microscopy are briefly discussed. A method is described for preparation of small crystals which can be observed in the electron microscope. A scheme for systematic chemical analysis of some metal cations of one component systems is presented. Typical resulst and electron micrographs are shown to illustrate the method.

5. Examination of Resin-Treated Fibers with the Electron Microscope. D. H. REYNOLDS AND J. A. RICH, *Monsanto Chemical Company, Dayton, Ohio* (Time 10 min.). —Fibers from some resin-treated fabrics have been studied with the electron microscope, with the aim of finding an explanation of the changed properties of the fibers. Fibers treated with four different types of resin were considered. Out of an extended study, two kinds of fibers have been chosen for discussion as showing the type of results obtained—light cotton sheet and 50/50 acetate-viscose. In the investigation, the fabrics were broken down mechanically by high speed stirring in water suspension, with careful avoidance of any chemical disintegration. The resulting "disintegration pattern" shown by the electron microscope was found to correlate well with observed physical properties of the treated fabrics.

6. A Pigment Dispersion Method for Electron Microscopy. HAROLD C. O'BRIEN, JR., *St. Joseph Lead Company, Monaca, Pennsylvania* (Time 10 min.).—A method is described which was devised primarily for the dispersion of zinc oxide pigment. It describes the technique necessary to "wet" the pigment particles and to form a strong, thin, transparent supporting film. The importance of the proper solvents and plasticizers for successful dispersions for cast films is discussed.

7. Techniques Useful with Pigmented Rubber Cements. L. H. WILLISFORD, *Research Laboratories, The Goodyear Tire & Rubber Company, Akron, Ohio* (Time 10 min.).— Milling pigments into rubber has long been known to be an excellent method for obtaining dispersions. In preparing suitable carbon black cement specimen films on water, the time lapsing between the initial spreading and specimen collection is important. Uniformly good results can also be obtained by dipping the supporting film into dilute suspensions. In case a specimen has a non-uniform appearance and interpretation proves difficult, it is helpful to photograph adjacent fields and to match the enlargements to form a consecutive series or panorama view; thereby, a beneficial impression of wholeness and a logical interdependence of the non-uniform portions is often obtained.

8. Electron Microscope Studies of Catalysts (Invited Paper). JOHN TURKEVICH, *Department of Chemistry, Princeton University, Princeton, New Jersey.*

9. Structure of Certain Muscle Fibrils as Revealed by the Use of Electron Stains (Invited Paper). C. E. HALL, MARIE A. JAKUS, AND F. O. SCHMITT, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

10. Fine Structure in the Fiber-Axis Macroperiod of Collagen Fibrils. FRANCIS O. SCHMITT, CECIL E. HALL, AND MARIE A. JAKUS, *Massachusetts Institute of Technology, Cambridge, Massachusetts* (Time 20 min.).—Electron micrographs of collagen fibrils appropriately treated with stains reveal fine structure within thr 640A fiber-axis macroperiod previously demonstrated by x-ray diffraction and electron microscope studies. Whereas electron micrographs of unstained fibrils show a single dark band in the macroperiod, stained fibrils show five dark bands, each having a characteristic position within the period and a characteristic relative density. Two of the bands have been resolved as doublets in highly stretched fibrils. The stains, being of high mass, produce sufficient contrasts to make

these structural details visible. It seems probable that the stains are taken up selectively by the predominantly hydrophilic regions in the fibrous structure. The location of the bands might, therefore, be expected to indicate the distribution of chemical groups with which water is normally associated. The positions and relative intensities of the bands seen with the electron microscope have been correlated with the small angle x-ray diffraction data, in particular with the relative intensities of the lower orders of the fiber-axis macroperiod. The agreement is quite satisfactory. In addition, the electron microscope observations explain some aspects of the variations in the x-ray pattern produced by the presence of water in the fiber.

11. Study of Tooth Structures with the Electron Microscope. C. H. GEROULD, *The Dow Chemical Company, Midland, Michigan* (Time 20 min.).—A discussion is presented on the use of the electron microscope with the polystyrene-silica replica technique in the study of tooth structures. A chart is presented to demonstrate the applicability of this technique to human teeth. The chart shows a cross section of a normal tooth with electron micrographs of both external and internal structures. A description of the preparation of tooth surfaces is given with the various steps in the preparation of the final silica replica film. A method is described to enable one to recognize better specific tooth regions in the electron microscope. A brief discussion is included on the interpretation of electron micrographs of tooth structures using either qualitative or quantitative stereoscopy. Ordinary electron micrograph slides show the structures of human teeth and also monkey, dog, and cow's teeth. A comparison is made between the electron micrographs of the dentin structure of a normal human tooth as compared to that of the dental fluorosis human tooth. Also are included Polaroid Vectograph (three-dimensional) slides which show the actual surface contours of distinctive tooth structures.

12. Thin Section Technique for Electron Microscopy. HAROLD C. O'BRIEN, JR., AND G. MURRAY MCKINLEY, *University of Pittsburgh, Pittsburgh, Pennsylvania* (Time 10 min.).—The paper includes a discussion of the techniques used in obtaining thin sections for electron microscopy by the use of the high speed "cyclone knife" microtome. Certain improvements have been made in the "cyclone knife" microtome, methods of handling sections, and in special treatments for biological tissues. Successful attempts have been made to section material other than tissue. Some discussion of embedding materials and technique is included.

13. Types of Morphology Found in Bacterial Viruses. THOMAS F. ANDERSON, *Eldridge Reeves Johnson Foundation for Medical Physics, University of Pennsylvania, Philadelphia, Pennsylvania;* M. DELBRUCK, *Vanderbilt University, Nashville, Tennessee;* AND M. DEMEREC, *Department of Genetics, Carnegie Institution of Washington, Cold Spring Harbor, New York* (Time 20 min.).—Five different viruses active on *E. coli* B have been identified using the electron microscope. Of these γ, T_4, and T_6 which belong to the same serological group have the complex structure of γ-phage with oval heads, $60\times80 m\mu$, containing a characteristic internal structure and having well-defined tails. The virus T_5, belonging to another serological group, has a structure very similar to that of a previously described staphylococcus virus with a round head $100 m\mu$ in diameter and an easily distinguished tail. The virus α, in a third serological group, has a dense head about $50 m\mu$ in diameter and a faint tail. Members of a fourth serological group have been studied, but the virus particles have not been identified as yet, possibly being smaller than any of those so far recorded. The morphological and serological classifications of these viruses are thus in good agreement. On the other hand, the range of hosts upon which these viruses are active has also been studied and the results indicate that the morphological and serological classifications have little to do with the factors which determine whether a bacterial strain is or is not a suitable host for a given virus.

14. On the Artifacts Produced by the Use of Distilled Water as an Intermediate Medium in the Mounting of Bacterial Specimens for the Electron Microscope. J. HILLIER AND A. KURKJIAN, *Radio Corporation of America, Princeton, New Jersey* (Time 10 min.).—A study is made of the appearance in the electron microscope of *E. coli* which have remained in distilled water for increasing periods of time after removal from a young growing culture. The appearance is compared with that observed in bacteria prepared quickly from a culture of corresponding age.

15. Electron Microscopy of Some Animal Viruses. D. GORDON SHARP, S. R. TAYLOR, I. W. MCLEAN, JR., DOROTHY BEARD AND J. W. BEARD, *School of Medicine, Duke University, Durham, North Carolina* (Time 15 min.).—The influence of impurities on electron micrographs of influenza virus has been studied by adding various substances to purified virus preparations which regularly give pictures showing little foreign matter. Addition of 5 percent NaCl did not obscure the virus nor greatly impair the individual images. With 5 percent sucrose they were less clear but still readily recognizable. Serum albumin 0.5 percent, however, reduced the virus images to uncertain blurs. Reduction of albumin content to 0.025 percent was still not sufficient to restore good results. Although albumin molecules are unresolvable, they frequently aggregate in drying on the collodion film into characteristic patterns. Animal viruses are usually prepared in buffers or in balanced saline solutions such as Ringer solution (0.16 *M*). Electron micrographs can readily be made on these preparations without dialysis or washing of prepared films, but sometimes fields without salt crystals are difficult to find. When $CaCl_2$ ($\frac{1}{4}$ to 1 percent) is used, much of this difficulty disappears, and in the case of equine encephalomyelitis and influenza viruses the particles are greatly increased in contrast. More uniform particle distribution is obtained also, and excess $CaCl_2$ can be removed from the collodion film by washing until optimum contrast is obtained for demonstration of internal structure. Increased contrast has not been found with rabbit papilloma virus nor with tobacco mosaic virus.

16. Observations on the Structure of Pyocyaneus Bacteriophage. E. W. SCHULTZ, P. R. THOMASSEN, AND L. MARTON, *Stanford University, Stanford University, California* (Time 10 min.).—An analysis of a number of electron micrographs (stereo and others) of pyocyaneus bacteriophage shows one component to be made up of a head and tail as described by Luria, Delbruck, and Anderson for certain other bacteriophages. The head of this component appears to be pentagonally shaped and to contain a filamenteous structure, the form of the filament frequently suggesting the letter W. There are, however, indications that its true projected shape approaches a distorted figure 8, the latter consisting of straight lines linked by short sharply curved portions. The tail is attached to the middle of one of the straight sections, from where it may go off at different angles. Comparison with the micrographs published by Luria, Delbruck, and Anderson shows that the structures observed in coli 'phage might well be interpreted similarly. The high density of the filaments suggests that they may possibly be composed of a distinctive nucleoprotein surrounded by a medium of lower density. Partial orientation of the heads of the 'phage particles may be interpreted as due to preferential settling out of the 'phage from its medium on to a flat surface. Such surfaces may result from shrinkage of the less dense portions of the protoplasm around the more rigid, skeleton-like filament. A spatial model illustrating the suggested structure of this bacteriophage will be presented.

17. Observations of Bulges on Acetobacter. C. H. GRAY, L. MARTON, AND E. L. TATIUN, *Stanford University, Stanford University, California* (Time 10 min.).—Electron microscope observations of different mutants of acetobacter, produced by x-ray irradiation, show a very great number of cells in different stages of division. Common to the different mutants is the presence of one or two darker areas of about 100 mμ in diameter in each cell. This darker area, interpreted as high concentrations of nucleo-protein, reveal themselves, under stereoscopic observations, as bulges above the level of the main body of the cell. An interpretation as artefacts, produced by shrinkage of the cells, seems highly unlikely, as the known rigidity of the cell wall is probably much greater than the rigidity of the cytoplasmic inclusions. On certain micrographs the same bulges appear quite transparent surrounded by dark rings. This latter, however, might be artefacts, as they show up only after extended electron bombardment.

18. An Unfamiliar Pattern of Bacteria Morphology. W. E. SMITH AND STUART MUDD, *University of Pennsylvania, Philadelphia, Pennsylvania* (Time 10 min.).—Bacteroides funduliformis presents a pattern of morphological change which differs markedly from that of ordinary bacteria. This deviation has led to completely unorthodox interpretations concerning the reproduction of this form. Electron microscopic studies give promise of resolving the issues in a way that ordinary microscopy could not have done.

19. Availability of Electron Micrograph for Instruction in Microbiology. HARRY E. MORTON, *School of Medicine, Philadelphia, Pennsylvania* (Time 10 min.).—The function of the Committee on Materials for Visual Instruction in Microbiology. The function of the Committee is to make available to teachers of microbiology, public health, or preventive medicine the various motion picture films, photographs, and electron micrographs prepared by research workers which might be useful aids in the visual instruction of the above mentioned subjects. The Committee is sponsored by the Society of American Bacteriologists and is attempting to make its work self-supporting. Workers in electron microscopy who have good electron micrographs of bacteria, rickettsiae, filterable viruses, or fungi, which might be useful for instructional purposes, are urged to communicate with the Chairman. The plan is that workers deposit with the Committee the original negative, a good duplicate negative, or a very good print from the original negative. From a master negative the Committee is able to provide any size lantern slide or print to teachers of microbiology. Appropriate legends and other descriptive matter are provided with each lantern slide or print so that such visual aids may be used intelligently. As materials become available for teaching purposes through the Committee, notices appear in the publications of the Society of American Bacteriologists, Biological Abstracts, and other reputable publications usually read by teachers of biology and medicine. The RCA Research Laboratories have made available to the Committee duplicate negatives, slides and prints of nearly 100 electron micrographs of biological subjects as the initial step in making available to teachers the many advances in microbiology brought about by the electron microscope. It is hoped that other workers in electron microscopy will make their work available for teaching purposes.

20. Electron Diffraction (Invited Paper). L. O. BROCKWAY, *Department of Chemistry, University of Michigan, Ann Arbor, Michigan.*

21. General Electric Electron Diffraction Apparatus (Invited Paper). C. H. BACHMAN, *General Electric Company, Schenectady, New York.*

22. Crystal Interference Phenomena in Electron Microscope Images. R. D. HEIDENREICH AND L. STURKEY, *The Dow Chemical Company, Midland, Michigan* (Time 15 min.).—The observation of electron reflections in electron microscope images is reviewed and further data are presented. The observations of the reflected beams with the objective limiting diaphragm removed and the determination of the planes responsible for the reflections by this means are described. The results of the dynamical theory of electron diffraction are briefly discussed and the values of the "characteristic" crystal thickness D_0 are computed. These values of D_0 are compared with the experimental values and are in reasonably good agreement for the MgO (200) reflections at 60, 96, and 103 kv, MgO (220) reflections, and CdO (200) reflections at 60 kv. The dyanamical theory accounts satisfactorily for the intensity variations except as modified by inelastic scattering and the results may be considered as experimental verification of the theory.

23. Further Developments on the Electron Microanalyzer. J. HILLIER AND R. F. BAKER, *Radio Corporation of America, Princeton, New Jersey* (Time 15 min.).—A discussion of further developments and difficulties encountered in the work on the microanalyzer will be given. This will include recent changes in the instrument and the results obtained. A description of the methods of calibration will be given. The initial tests on the use of the instrument for vapor and gas analyses will be described as well as some of the preliminary results.

24. Study of Age Hardening Alloys with the Electron Microscope Using Formvar Replicas? Copper-Beryllium and Iron-Molybdenum (Invited Paper). DAVID HARKER, *General Electric Company, Schenectady, New York.*

25. Correlation of MgO Particle Size Determination by Electron Microscope and X-Ray Diffraction. L. S. BIRKS AND H. FRIEDMAN, *U. S. Naval Research Laboratory, Washington, D. C.* (Time 15 min.).—Magnesium oxide, obtained by heating commercial magnesium carbonate in air, was chosen for comparison of particle size determination by the electron microscope and by x-ray diffraction. This system was selected because the carbonate converted in this manner gives approximately spherical particles of very uniform size for a given conversion temperature and heating period. By varying the heating periods and temperatures, it was possible to produce particle sizes from 40–100A. Microscope magnifications obtained from an optically calibrated grating replica were accurate to ±5 percent. An x-ray Geiger counter spectrometer was employed to measure the shape of the diffraction lines of the MgO powder samples. The widths at half-maximum were measured with an accuracy of $\pm\frac{1}{4}$ minute of arc in 2θ. The particle size determinations by the two methods agreed to ±10 percent for the range 100–1000A.

26. A Modified Replica Technique Applied to the Study of Organic and Inorganic Surfaces. R. BOWLING BARNES, CHARLES J. BURTON, AND ROBERT G. SCOTT, *American Cyanamid Company, Stamford, Connecticut* (Time 15 min.).—The polystyrene-silica replica technique developed by Heidenreich has achieved remarkable success in metallurgical problems. A modification of this method has been developed in which a thin polystyrene film is used for formation of the original impression. The entire operation is carried out at a temperature of 150°Ç and with approximately two pounds per square inch pressure. Silica replicas are then formed by the usual evaporation technique. The method is described in detail and its application to replica formation of organic as well as inorganic surfaces is discussed.

27. On the Silica Replica Technique with the Electron Microscope. R. F. BAKER AND F. H. NICOLL, *Radio Corporation of America, Princeton, New Jersey* (Time 15 min.).—Some exploratory investigations on the deposition of silica by chemical methods are described. Silica produced by hydrolizing silicon tetrachloride in the vapor phase at the surface of the negative polystyrene replica has yielded some good replicas. The need for further research and for understanding of the necesssary control is stressed.

28. Polaroid Vectographs for Use in Electron Microscopy (Invited Paper). PAUL E. HORD, *Polaroid Corporation, Cambridge, Massachusetts.*

Erratum: Some Physical Properties of Elastomers at Low Temperature

[J. App. Phys. **16**, 3 (1945)]

H. E. GREENE AND D. L. LOUGHBOROUGH

IN the paper "Some Physical Properties of Elastomers at Low Temperature" Figures 10 and 11 were interchanged. The captions were correct.